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ECOLOGICAL STUDIES ON *TRIPHLEPS SINUI*, NARAYANAN AND CHATTERJI (RHYNCHOTA : ANTHOCORIDAE), A PREDATOR OF SOME STORED CEREAL PESTS

By

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INTRODUCTION

Storage pests are generally controlled by the use of insecticides. But there are a few natural enemies of some storage pests like *Microbracon gelechiae* which have been employed to control *Gnorimoschema operculella*, Zell., a pest of potato in storage. Recently Pingale (1954) has reported successful control of *Ephestia cautella* Walk., and *Alphitobius diaperinus* Panz., by *Amphibolus venator* Klug., a bug predator of these storage pests. Chatterji (1951) observed a species of *Triphleps* predating on *Latheticus oryzae* Waterh. and *Oryzaephilus surinamensis* Linn. This bug predator was later on found new to science and was described by Narayanan and Chatterji (1952). The biology of *T. sinui* was studied at room temperature and humidity (Chatterji, 1955). In the above studies the predator was found to have certain advantages. The adults as well as the nymphs were active predators, attacking all the immature stages of the pests except the egg and the advanced pupa. Comparative studies of the ecology of the bug and its principal hosts are necessary to estimate how far this predator can be usefully employed in the biological control of stored grain pests. Consequently, during the course of present investigations the effect of temperature and humidity on *T. sinui* was studied.

MATERIAL AND METHOD

Triphleps sinui and its host *Latheticus oryzae* Waterh., used in these studies were reared separately from a single pair *i.e.* one male and a female under a temperature and relative humidity varying from 25°C - 27°C and 65% to 70% respectively.

Pure sterilized wheat flour was given as food to *L. oryzae*. Freshly laid eggs from the cultures were taken for the present studies. For maintaining the required temperatures of 20°C, 25°C, 30°C and 35°C, electric incubators manufactured by Messrs Baired and Tatlock Ltd., London, were used. The lower temperature namely 20°C and sometimes 25°C were maintained in the above by running ice-cold water through the outer jacket of the incubators. The required percentage of relative humidity namely 32%, 50% and 75% were maintained in desiccators [4·5″ (height) × 2·5″ (diameter)] by means of potassium hydroxide solution in distilled water. In these desiccators the material for studies was kept in small copper wire-gauze (80 mesh) cages, the size being 1″ in height and 0·7″ in diameter. The bottom of the cage was made of white tin sheet. Different stages of the predator, from the third nymphal instar to the adult stage, were placed in such wire-gauze cages. Difficulty, however, arose in the case of eggs, 1st and 2nd nymphal instars which being rather small were either lost or got crushed at the time of day to day examination. Hence small specimen glass tubes (2″ × 0·5″) open at the top were used to overcome the above difficulty. The eggs were kept in these glass tubes which were kept erect in the wire-gauze cages. The nymphs from these specimen tubes were transferred directly to the wire-gauze cages after the completion of the second nymphal stage.

OBSERVATION AND RESULTS

Incubation period :

The incubation period varied from 4·3 to 11·3 days on an average under different experimental conditions. In many cases under high temperatures and high humidities and in some cases under low temperatures and low humidities the eggs were found to be shrivelled. The latter did not hatch. The analysis of results for the effect of different temperatures and humidities on the incubation period is given below :

Temp. / R.H.	20°C	25°C	30°C	35°C	Average
32%	11·33	8·33	6·33	5·33	7·83
50%	10·83	7·17	5·83	5·00	7·21
75%	10·00	6·83	5·50	4·33	6·66
Average	10·72	7·44	5·89	4·89	

'F' test highly significant for temperature
S. Em = ± 0·13
C. D. at 5% level = 0·36
C. D. at 1% level = 0·48

'F' test highly significant for humidity
S. Em = ± 0·11
C. D. at 5% level = 0·31
C. D. at 1% level = 0·41

'F' test for intraction not significant
S. Em = ± 0·22

R. H. denotes Relative Humidity. Temp. denotes temperature.
S. Em = Standard error of the mean.
C. D. = Critical difference.

Conclusions : Differences amongst the individual temperatures, namely, 20°C, 25°C, 30°C and 35°C were highly significant. A temperature of 35°C was the best, the incubation period being the shortest, followed by 30°C, 25°C and 20°C. On the other hand, the differences between the three R. H. namely, 32%, 50% and 75% were highly significant and at 75% R. H. the incubation period was the shortest followed by 50% and 32% R. H.

Nymphal periods :

The first, second, third, fourth and fifth nymphal periods varied on an average from 4·0 to 8·5 days, 3·0 to 5·1 days, 3·0 to 6·0 days, 2·6 to 5·0 days and from 3·1 to 5·5 days respectively with food in different combinations of temperatures and humidities. The total nymphal period varied from 14·0 days to 30·2 days on an average under different combinations of temperatures and humidities as given below :

Temp.	20°C	25°C	30°C	35°C	Average
R.H.					
32%	30·17	24·33	21·17	15·50	22·79
50%	25·33	16·17	16·50	14·67	18·17
75%	23·33	17·83	16·67	14·00	17·96
Average	26·28	19·44	18·11	14·72	

'F' test highly significant for temperature	'F' test highly significant for humidity	'F' test highly significant for interaction
S. Em = ± 0·31	S. Em = ± 0·26	S. Em = ± 0·53
C.D. at 5% level = 0·86	C.D. at 5% level = 0·75	C.D. at 5% level = 1·50
C.D. at 1% level = 1·15	C.D. at 1% level = 0·99	C.D. at 1% level = 1·99

Conclusions : A temperature of 35°C was found to be most suitable which was followed by 30°, 25°, and 20°C respectively. As regards relative humidity 75% and 50% were found to be favourable being followed by 32%. The total nymphal period under 50% R.H. and 75 R.H. did not differ significantly between themselves. The interaction between different levels of humidity and temperature was significant. A combination of 35°C and 75% R. H. was found to be significantly more favourable than the rest. This combination was the best followed by 35°C and 50% R. H.

Logevity of unmated adults with food :

Male : The longevity of unmated male with *Lathetieus oryzae* grubs as food varied from 11·5 to 26·5 days on an average in different temperatures and humidities as given below :—

Temp. / R.H.	20°C	25°C	30°C	35°C	Average
32%	16·83	20·50	22·33	11·50	17·79
50%	19·00	22·17	26·50	12·00	19·92
75%	19·50	22·00	22·67	13·33	19·37
Average	18·44	21·56	23·83	12·28	

'F' test highly significant for temperature	'F' test highly significant for humidity	'F' test highly significant for interaction
S. Em = ± 0·29	S. Em. = ± 0·25	S. Em = ± 0·51
C.D. at 5% level = 0·83	C.D. at 5% level = 0·72	C.D. at 5% level = 1·44
C.D. at 1% level = 1·11	C.D. at 1% level = 0·95	C.D. at 1% level = 1·91

Conclusions : A temperature of 30°C showed more favourable longevity as the adult lived upto 26·5 days on an average. This was followed by the temperatures of 25°, 20° and 35°C. The longevity differed significantly at all these temperatures. The humidity differences were significant between 75% and 32%, 50% and 32% but did not differ significantly between 50% and 75% R. H. A combination of 30°C and 50% R. H. was found to be significantly more favourable than the rest.

Female : The longevity of unmated female varied from 12·2 to 27·3 days on an average in different temperatures and humidities as given below :

Temp. / R. H.	20°C	25°C	30°C	35°C	Average
32%	21·50	21·83	22·17	12·17	19·42
50%	23·33	22·33	27·33	13·00	21·50
75%	23·67	23·00	25·83	14·33	21·71
Average	22·83	22·39	25·11	13·17	

'F' test highly significant for temperature	'F' test highly significant for humidity	'F' test highly significant for interaction
S. Em = ± 0·27	S. Em = ± 0·24	S. Em = ± 0·47
C.D. at 5% level = 0·77	C.D. at 5% level = 0·66	C.D. at 5% level = 1·33
C.D. at 1% level = 1·02	C.D. at 1% level = 0·88	C.D. at 1% level = 1·76

Conclusions : The temperature of 30°C showed a highly significant effect. At this temperature the adults could live for the largest number of days i.e. 27·3 days. A higher temperature of 35°C proved to be detrimental. The differences between 20°C and 25°C were, however, not significant. At higher humidity of 50% or 75% the longevity was the maximum. There was, however, no significant difference in longevity between 50% and 75% R. H. Interaction between different levels of temperature and humidity was significant and a combination of 30°C with 50% R. H. proved to be the best.

Longevity of mated adults with food :

Male : The longevity of mated males varied from 8·8 to 23·2 days on an average under different temperature and humidity combinations as follows :

Temp.	20°C	25°C	30°C	35°C	Average
R. H.					
32%	14·67	17·17	20·17	8·83	15·21
50%	16·50	19·00	23·17	10·67	17·33
75%	17·67	20·00	21·67	12·00	17·83
Average	16·28	18·72	21·67	10·50	

'F' test highly significant for temperature	'F' test highly significant for humidity	'F' test highly significant for interaction
S. Em. = ± 0·18	S. Em = ± 0·16	S. Em = ± 0·32
C.D. at 5% level = 0·51	C.D. at 5% level = 0·45	C.D. at 5% level = 0·89
C.D. at 1% level = 0·68	C.D. at 1% level = 0·59	C.D. at 1% level = 1·19

Conclusions : All the temperatures differed significantly, 30°C being the best, followed by 25°, 20° and 35°C. As regards relative humidity, 32% R. H. differed significantly with 50% and 75% R. H. at 1% level but the differences between 50% and 75% R. H. were significant at 5% level only. A combination of 50% R. H and 30°C being the best, followed by 75% R. H. and 30°C.

Female : The longevity varied from 10·3 to 27·3 days on an average under different combinations of temperature and humidity as mentioned below :

Temp.	°C	25°C	30°C	35°C	Average
R. H.					
32%	19·50	18·83	21·33	10·30	17·61
50%	20·50	20·00	27·33	11·00	19·71
75%	21·50	21·00	24·83	13·33	20·16
Average	20·50	19·94	24·66	11·54	

'F' test highly significant for temperature	'F' test highly significant for humidity	'F' test highly significant for interaction
S. Em = ± 0·20	S. Em = ± 0·18	S. Em = ± 0·35
C.D. at 5% level = 0·58	C. D. at 5% level = 0·50	C.D. at 5% level = 1·00
C.D. at 1% level = 0·77	C. D. at 1% level = 0·66	C.D. at 1% level = 1·33

Conclusions : At 30°C the longevity of mated adult female with food was the longest, while it was the shortest at 35°C. There was, however, no significant difference between 20°C and 25°C and also between 75% and 50% R. H. The combined effect of temperature and humidity was best indicated at a combination of 30°C and 50% R. H. at which the longevity was maximum.

Longevity of starved unmated adults :

Male : The average longevity without food varied from 4·0 to 12·0 days. The results of analysis for different temperatures and humidities are given below :

Temp.	20°C	25°C	30°C	35°C	Average
R. H.					
32%	10·00	11·00	8·50	4·00	8·37
50%	11·33	10·00	11·00	5·00	9·33
75%	12·00	8·17	9·00	6·67	8·96
Average	11·11	9·72	9·50	5·22	

'F' test highly significant for temperature	'F' test highly significant for humidity	'F' test highly significant for interaction
S. Em = ± 0·19	S. Em = ± 0·17	S. Em = ± 0·34
C.D. at 5% level = 0·55	C.D. at 5% level = 0·47	C.D. at 5% level = 0·95
C.D. at 1% level = 0·73	C.D. at 1% level = 0·63	C.D. at 1% level = 1·26

Conclusions : A temperature of 20°C was the best followed by 25°C, 30°C and 35°C. Fifty per cent R. H. was the best followed by 75% and 32% R. H. The interaction between the various levels of temperature and humidity was highly significant and the best combination was 20°C and 50% R. H., followed by 30°C and 50% R. H.

Female : The longevity varied from 4·8 to 14·8 days on an average under different combinations of temperature and humidity as given below :

Temp.	20°C	25°C	30°C	35°C	Av rage
R. H.					
32%	13·00	12·17	10·17	4·83	10·04
50%	14·00	12·33	12·83	6·67	11·46
75%	14·83	10·33	10·67	9·17	11·25
Average	13·94	11·61	11·22	6·89	

'F' test highly significant for temperature	'F' test highly significant for humidity	'F' test highly significant for interaction
S. Em = ± 0·17	S. Em. = ± 0·15	S. Em. = ± 0·30
C.D. at 5% level = 0·49	C.D. at 5% level = 0·42	C.D. at 5% level = 0·85
C.D. at 1% level = 0·65	C.D. at 1% level = 0·56	C.D. at 1% level = 1·13

Conclusions : A temperature of 20°C was the best, followed by 25°C, 30°C and 35°C. The humidity of 50% was the best, followed by 75% and 32%. But the difference between 75% and 50% R. H. was not significant. The interaction between various levels of temperature and humidity was highly significant. A combination of 20°C and 75% R. H. was the best.

Longevity of starved mated adults :

Male : The mated male lived from 3·0 to 10·5 days on an average without food. The analysis of results is given below :

Temp.	20°C	25°C	30°C	35°C	Average
R. H.					
32%	7·00	9·00	7·83	3·00	6·71
50%	10·33	8·00	9·17	4·33	7·96
75%	10·50	7·00	7·83	5·33	7·66
Average	9·28	8·00	8·28	4·22	

'F' test highly significant for temperature	'F' test highly significant for humidity	'F' test highly significant for interaction
S. Em = ± 0·15	S. Em = ± 0·13	S. Em = ± 0·27
C.D. at 5% level = 0·44	C.D at 5% level = 0·38	C.D. at 5% level = 0·76
C.D. at 1% level = 0·58	C.D at 1% level = 0·50	C.D. at 1% level = 1·00

Couclusions A temperature of 20°C was most favourable being followed by 30°C, 25°C and 35°C. The differences in the longevity between 25°C and 30°C were not significant. 50% R.H was most favourable followed by 75% and 32% R.H. The differences were, however, not significant between 50% and 75% R. H, A combination of 20°C and 75% R. H. was the best, being followed by 20°C and 50% R. H. The next suitable combination was a temperature of 30°C and 50% R. H.

Female : The longevity varied from 4·0 to 11·7 days on an average under different combinations of temperature and humidity as given below :

Temp.	20°C	25°C	30°C	35°C	Average
R. H.					
32%	9·33	10·33	10·00	4·00	8·41
50%	11·33	8·83	11·00	5·00	9·04
75%	11·67	9·17	11·17	6·17	9·54
Average	10·78	9·44	10·72	5·06	

'F' test highly significant for temperature	'F' test highly significant for humidity	'F' test highly significant for interaction
S. Em = ± 0·16	S. Em = ± 0·14	S. Em = ± 0·27
C.D. at 5% level = 0·44	C.D. at 5% level = 0·38	C.D. at 5% level = 0·77
C.D. at 1% level = 0·59	C.D. at 1% level = 0·51	C.D. at 1% level = 1·02

Conclusions : A temperature of 20°C was the best, followed by 30°C, 25°C and 35°C. The differences in the longevity of mated and starved females under 20°C and 30°C was not significant, but both these temperatures showed a significant difference over 25°C and 35°C. The best humidity was 75% followed by 50% and 32% R. H. The differences between 50% and 75% R. H. were significant at 5% level only. A combination of 20°C and 75% R. H. was the best followed by 20°C and 50% R. H. ; 30°C and 75% R. H. and lastly 30°C and 50% R. H.

Mortality of eggs :

The mortality percentage of eggs varied from 8·3 to 83·7 on an average under different combinations of temperature and humidity as mentioned below :

Temp.	20°C	25°C	30°C	35°C	Average
R. H.					
32%	45·00	14·83	13·83	83 67	39·33
50%	36·00	8·50	9·17	78·17	32·96
75%	25·33	8·33	12·00	73·83	29·87
Average	35·44	10·55	11·67	78·56	

'F' test highly significant for temperature
S. Em = ± 0·75
C.D. at 5% level = 2·13
C.D. at 1% level = 2·83

'F' test highly significant for humidity
S. Em = ± 0·65
C.D. at 5% level = 1·84
C.D. at 1% level = 2·45

'F' test highly significant for interaction
S. Em = ± 1·30
C.D. at 5% level = 3·69
C.D. at 1% level = 4·91

Conclusions : Temperatures of 35°C and 20°C showed very high mortality percentage of eggs, whereas 25°C and 30°C were best suited temperatures for the viability of eggs. The differences between the later two were, however, not significant . 75% R. H. was the best, followed by 50% and 32% R. H. A combination of 25°C and 75% R. H. was the best, followed by 25°C and 50% R. H. and 30°C 50% R. H., as in these combinations the mortality of the eggs was less than other combinations.

Mortality of first instar nymph (with food) :

The mortality of the first instar nymph was found to vary from 9·5% to 76·0% on an average under different combinations of temperature and humidity as mentioned below :

Temp.	20°C	25°C	30°C	35°C	Average
R. H.					
32%	36·33	25·00	14·17	76·00	37·87
50%	32·17	21·50	10·00	58·00	30·92
75%	27·00	17·17	9·50	40·17	23·46
Average	31·83	21·22	11·22	58·06	

'F' test highly significant for temperature
S. Em = ± 0·37
C.D. at 5% level = 1·04
C.D. at 1% level = 1·38

'F' test highly significant for humidity
S. Em = ± 0·32
C.D. at 5% level = 0·90
C.D. at 1% level = 1·20

'F' test highly significant for interaction
S. Em = ± 0·64
C.D. at 5% level = 1·80
C.D. at 1% level = 2·39

Conclusions : A temperature of 30°C was the best, the percentage mortality being the least, and this was followed by 25°C, 20°C and 35°C. In the case of humidity, 75% R. H. was found to be the best, followed by 50% and 32% R. H. The interaction between various levels of temperature and humidity was highly significant. The best combination was 75% R. H. and 30°C temperature followed by 50% R. H. and 30°C temperature.

Longevity of the first nymphal instar (without food) :

The longevity was found to vary from 11·3 hours to 88·0 hours on an average under different combinations of temperature and humidity as given below :

Temp.	20°C	25°C	30°C	35°C	Average
R. H.					
32%	88·0	56·0	60·0	24·0	57·0
50%	72·0	36·0	40·0	15·7	40·9
75%	48·0	28·0	32·0	11·3	29·8
Average	69·3	40·0	44·0	17·0	

'F' test highly significant for temperature	'F' test highly significant for humidity	'F' test not significant for interaction
S. Em = ± 2·66	S. Em = ± 2·31	S. Em = ± 4·61
C.D. at 5% level = 7·52	C.D. at 5% level = 6·53	
C.D. at 1% level = 10·01	C.D. at 1% level = 8·69	

Conclusions : The temperature of 20°C was best followed by 30°C, 25°C and 35°C. The longevity differences between 25°C and 30°C were not significant. The humidity of 32% R. H. was best followed by 50% and 75% R. H.

Total number of grubs predated during the nymphal period :

Male nymph : The total number of grubs predated on an average varied from 22·2 to 28·3 as mentioned below :

Temp.	20°C	25°C	30°C	35°C	Average
R. H.					
32%	26·00	28·33	27·17	25·67	26·79
50%	25·33	24·33	27·33	26·50	25·87
75%	26·33	26·17	25·50	22·17	25·04
Average	25·89	26·28	26·67	24·78	

'F' test highly significant for temperature	'F' test highly significant for humidity	'F' test highly significant for interaction
S. Em = ± 0·40	S. Em = ± 0·34	S. Em = ± 0·69
C.D. at 5% level = 1·13	C.D. at 5% level = 0·98	C.D. at 5% level = 1·95
C.D. at 1% level = 1·50	C.D. at 1% level = 1·30	C.D. at 1% level = 2·59

Conclusions : There were significant differences, regarding total number of grubs predated, between 25°C and 35°C and 30°C and 35°C. However, difference between 20°C, 25°C and 30°C were not found to be significant. It was found that

the number of grubs predated under 50% and 75% and 32% and 50% R.H. did not differ between themselves significantly. The differences between 32% and 75% R. H. were found to be significant. The interaction between the different levels of humidity and temperature was highly significant. A combination of 25°C and 32% R.H. was the best as at this combination the nymphs predated on a larger number of host grubs.

Female nymph : The total number of grubs predated by a female nymph varied on an average from 25·7 to 31·0 under different combinations of temperature and humidity as given below :

Temp.	20°C	25°C	30°C	35°C	Average
R. H.					
32%	29·50	29·00	31·00	28·33	29·46
50%	27·83	29·67	28·67	27·50	28·42
75%	27·50	29·67	28·83	25·67	27·92
Average	28·28	29·45	29·50	27·17	

'F' test highly significant for temperature
S. Em = ± 0·38
C.D. at 5% level = 1·08
C.D. at 1% level = 1·44

'F' test highly significant for humidity
S. Em = ± 0·33
C.D. at 5% level = 0·94
C.D. at 1% level = 1·25

'F' test not significant for interaction
S. Em = ± 0·66

Conclusions : At 5% level, the number of host grubs predated by the female were found to be significant between 20°C and 25°C, 30°C and 35°C. The differences between 25°C and 35°C and 30°C and 35°C were found to be significant at 1% level. However, the number of host grubs predated by the female did not differ significantly between 25°C and 30°C. As regards humidity, at 1% level the results between 32% and 50% R. H. and between 50% and 75% R. H. did not differ significantly but at 5% level the number of grubs predated under 32% R. H. was significantly more than that under 50% or 75% R. H.

Total number of grubs predated by unmated adult :

Male : The total number of grubs predated by an unmated adult male till its natural death varied from 16·0 to 55·5 on an average under different conditions of temperature and humidity as given below :

Temp.	20°C	25°C	30°C	35°C	Average
R. H.					
32%	16·00	29·83	46·50	32·17	31·12
50%	20·00	34·33	55·50	41·33	37·79
75%	20·33	39·83	45·33	46·50	37·99
Average	18·78	34·66	49·11	40·00	

'F' test highly significant for temperature
S. Em = ± 0·32
C.D. at 5% level = 0·91
C.D. at 1% level = 1·21

'F' test highly significant for humidity
S. Em = ± 0·28
C.D. at 5% level = 0·79
C.D. at 1% level = 1·05

'F' test highly significant for interaction
S. Em = ± 0·56
C.D. at 5% level = 1·58
C.D. at 1% level = 2·10

Conclusions : A temperature of 30°C was most favourable which was followed by 35°C, 25°C and 20°C. The best results were obtained at 75% R. H. followed by 50% and 32% R. H. The differences between 50% and 75% R. H. were not significant. The interaction between different levels of temperature and humidity was significant. The best combination was 30°C and 50% R. H. where a higher number of grubs were predated.

Female : The total number of grubs predated by an unmated adult female till its natural death varied from 20·2 to 60·2 on an average under different conditions of temperature and humidity as mentioned below :

Temp.	20°C	25°C	30°C	35°C	Average
R. H.					
32%	20·17	38·17	49·83	36·17	36·08
50%	23·00	37·17	60·17	45·50	41·46
75%	24·50	42·33	47·00	48·67	40·62
Average	22·56	39·22	52·33	43·45	

'F' test highly significant for temperature	'F' test highly significant for humidity	'F' test highly significant for interaction
S. Em = ± 0·29	S. Em = ± 0·25	S. Em = ± 0·50
C.D. at 5% level = 0·81	C.D. at 5% level = 0·70	C.D. at 5% level = 1·40
C.D. at 1% level = 1·07	C.D. at 1% level = 0·93	C.D. at 1% level = 1·87

Conclusions : A temperature of 30°C was found to be most favourable which was followed by 35°C, 25°C and 20°C. A relative humidity of 50% was most favourable which was followed by 75% and 32% R. H. The interaction between the different levels of humidity and temperature was highly significant. The best combination was 30°C and 50% R. H. which was followed by 30°C and 32% R. H.

Fecundity with food :

The rate of egg laying on an average per female varied from 2 to 9 eggs per day and the total varying from 47·5 to 116·8 eggs on an average in its whole life under different combinations of temperature and humidity as given below :

Temp.	20°C	25°C	30°C	35°C	Average
R. H.					
32%	47·50	96·67	113·50	40·00	74·42
50%	31·00	100·50	116·83	60·67	77·25
75%	63·33	88·00	82·50	78·67	78·12
Average	47·28	95·06	104·28	59·78	

'F' test highly significant for temperature	'F' test highly significant for humidity	'F' test highly significant for interaction
S. Em = ± 0·87	S. Em = ± 0·75	S. Em = ± 1·50
C.D. at 5% level = 2·46	C.D. at 5% level = 2·13	C.D. at 5% level = 4·26
C.D. at 1% level = 3·27	C.D. at 1% level = 2·83	C.D. at 1% level = 5·66

Conclusions : The temperature of 30°C was best followed by 25°C, 35°C and 20°C. The relative humidity of 75% was most suitable followed by 50% and 32% R. H. The differences between 50% and 75% R. H. were, however, not significant. The interaction between different levels of temperature and humidity was highly significant and the combination of 30°C and 50% R. H. or 32% R. H. was the best for laying a large number of eggs.

Fecundity in the absence of host grubs :

The total number of eggs laid by a female without any food varied from 7·5 to 29·3 on an average under different combinations of temperature and humidity as given below :

Temp.	20°C	25°C	30°C	35°C	Average
R. H.					
32%	7·50	11·50	20·67	26·33	16·50
50%	7·83	15·50	29·33	27·83	20·12
75%	9·50	17·00	25·83	28·00	20·08
Average	8·28	14·67	25·28	27·39	

'F' test highly significant for temperature	'F' test highly significant for humidity	'F' test highly significant for interaction
S. Em = ± 0·41	S. Em = ± 0·35	S. Em = ± 0·71
C.D. at 5% level = 1·16	C.D. at 5% level = 1·00	C.D. at 5% level = 2·01
C.D at 1% level = 1·55	C.D. at 1% level = 1·33	C.D. at 1% level = 2·67

Conclusions : The temperature of 35°C was best followed by 30°C, 25°C and 20°C. The relative humidities of 75% and 50% were not significant between themselves but were significant over 32% R.H. The interaction between different levels of temperature and humidity was highly significant. The combination of 30°C and 50% R.H. was most favourable.

DURATION OF DIFFERENT STAGES IN DAYS (AVERAGE) OF *LATHETICUS ORYZAE*, HOST OF *TRIPHLEPS SINUI.*

It will be seen from Table 1 that the total larval period at 20°C and 32% R.H. was recorded to be 30 days and at 35°C and 32% R.H. was recorded to be 21 days and at 35°C and 75% R.H. it was found to be 28 days. Similarly the duration of pupal stages of the host was also observed and it was found that at 20°C and 32% R.H. it was 10·0 days whereas at 35°C and 50% R.H. it was 4 days. The adult stage also showed a greater degree of variation at 20°C and 32% R.H. which was 32 days and 52 days at 35°C and 75% R.H. and 30·5 days at 30°C and 75% R.H.

DISCUSSION

In discussing the results obtained that have got applied importance in the control of those pests which is the direct function of the economic entomologist, we may very briefly make a relevant survey of the contributions made by other

workers so that the results obtained during the course of the present studies may be judged in their entirety and in comparison with those already obtained.

(*i*) *Duration of incubation period and different larval instars.* Jones (1930) after conducting a number of experiments on the effect of temperature and humidity on *Cimex lectularius* Linn. concluded that temperature and relative humidity are important factors in the incubation period of the eggs and the duration of life of nymphs without food. According to him, length of life inversely with the increase in degrees of temperature about 13°C. He added further that relative humidities below 50% are lethal to the nyphs in less time than those between 50% and 75% R. H. Pruthi (1940) in his presidential address on ecology and control of insects stated that the effect of temperature and humidity on the life of insects go together and is very much dependent on each other.

In the present investigations it was observed that a lower temperature (20°C) and a lower relative humidity (32%) increased the duration of incubation period. At higher temperature (35°C) and lower humidity (32%) the incubation period was more than under higher temperature (32°C) and higher humidity (75%).

TABLE I

Duration of different stages in days (average) of *L. Oryzae* host of *T. sinui*

Stages	20°C temperature			25°C temperature			30°C temperature			35°C temperature		
	32% R.H.	50% R.H.	75% R.H.	32% R.H.	50% R.H.	75% R.H.	32% R.H.	50% R.H.	75% R.H.	32% R.H.	50% R.H.	75% R.H.
1	2	3	4	5	6	7	8	9	10	11	12	13
Larval	30·0	29·0	27·0	25·0	24·0	23·0	22·5	21·0	20·2	21·0	26·0	28·0
Pupal	10·0	9·0	8·6	8·0	7·8	7·1	6·8	6·1	6·0	5·0	4·0	4·4
Adult	39·0	36·0	35·0	34·0	33·4	32·5	32·2	31·0	30·5	41·0	47·0	52·0

Considering, however, the mortality of the eggs and the duration of the incubation period the optimum temperature was 30°C while the optimum humidity was near about 50% to 75%.

The influence of temperature on the duration of different nymphal instars of *T. sinui* shows that a lower temperature (20°C) increased it. With the increase in humidity the nymphal duration was shortened. As was in the case of egg the effective zone of temperature and humidity for the development of the nymphs also lay somewhere near about 30°C and 50% to 75% R.H. respectively.

(*ii*) *Longevity.* Johnson (1940) worked out the longevity of the fasting bed bug under experimental conditions and concluded that the unmated females live longer than the mated ones, but no effect of mating on survival was noticed with males. He found mated males to outlive mated females except at very low temperatures. He also found that virgin females live longer than unmated males.

The present investigations on the effect of temperature and humidity on the longevity of adults namely mated, unmated; with food and without food etc. showed

that the females of *T. sinui* lived longer irrespective of any other factor. Mating was found to decrease the longevity of the adults more so in the case of the male while the longevity of the adults with food was more than without food, the fed male dying earlier than the fed female under all the experimental temperatures and humidities. It was also seen that the male and female, whether mated or unmated, lived longer with food i.e. in presence of host grubs under a combination of 30°C temperature and 50% – 75% relative humidity. While on the other hand, similar adults, both male and female favoured a combination of 20°C temperature and 50% – 75% relative humidity in the absence of any host grub.

(*iii*) *Fecundity.* In the present investigations it was found that the temperature played an important part in increasing or reducing the rate of oviposition in *T. sinui.* Humidity had less influence on its fecundity than temperature. Maximum egg-laying was observed under a combination of 30°C temperature and between 50% to 75% relative humidity. Although at 35°C the egg-laying was maximum yet due to the mortality of the eggs and the shortening of the oviposition period this temperature could not be termed as favourable.

(*iv*) *Feeding.* The present studies showed that under high temperature and high humidity the rate of feeding was accelerated than at lower ones. But as the longevity was shorter at higher temperature and higher humidity the maximum number of host—grubs predated by *T. sinui,* both in nymphal and the adult stages irrespective of other factors like mating and sex were under a combination of 30°C and 32% to 50% relative humidity.

(*v*) *Comparison between the host* (L. oryzae) *and the predator.* In the present investigations it was found that *T. sinui,* a predator of *Latheticus oryzae* Waterh., developed very well at temperatures between 30°C to 35C°, within which lay the threshold of its development, but at this temperature the predator *T. sinui* did not do well as it was harmful for the younger stages. The most favourable temperature for *L. oryzae* was found to be in between 30°C and 35°C. *T. sinui* can hardly withstand the higher temperature namely 35°C.

The other limiting factor was cannibalism which was sometimes found to occur in this species, as was recorded by Chatterji (1955). Cannibalism was, however, observed only when there was a shortage of food.

From the present studies, it can be concluded that the predator has certain definite advantages. There is a fairly high prolificacy and longevity of the adults. The adults as well as the nymphs are active predator, attacking all the immature stages of the host except the egg and the advanced pupae. However judging from the several limiting factors like temperature, cannibalism etc., it can be said that although *Triphleps sinui* Narayanan and Chatterji, cannot be employed with complete success to control *Latheticus oryzae* Waterh., a fairly serious pest of milled cereal products under natural conditions of storage, yet it can be used to check the rapid multiplication of the pest especially in those months when the godown temperature does not rise above 30°C.

SUMMARY

The present investigation attempt to determine the effect of different temperatures and humidities on the duration of different stages, longevity, fecundity,

feeding etc. of *Triphleps sinui* Narayanan and Chatterji. It has been found that :—

1. Lower temperature (20°C) and lower humidity (32%) lengthen the incubation period and also the nymyhal period. Higher temperature and high humidity generally shortens the duration of the above.
2. Females live longer irrespective of any other factor. Mating was found to decrease the longevity of the adults, more so in the case of males while longevity of the adults which good was more than without food. The female, whether mated or unmated, lived longer with food under a combination of 30°C temperature and 50% to 75% relative humidity. On the other hand, similar adults favoured a combination of 20°C and 50% to 75% relative humidity in the absence of any host grub.
3. Temperature plays an important part in increasing or reducing the rate of oviposition. Generally humidity has less influence on the fecundity than temperature.
4. High temperature and high humidity accelerate the rate of feeding.
5. On a comparison with its host namely *Latheticus oryzae* Waterh., it has been observed that although there is a fairly high prolificacy and longevity of the adult predator yet there are some limiting factors like temperature, cannibalism etc. which stands in the way of the predator in controlling its host successfully in naturally conditions of storage particularly during those months when the godown temperature rises above 30°C.

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PATHOLOGICAL STUDIES OF *COLLETOTRICHUM CAPSICI* SYD (BUT *et* BISBY) CAUSING LEAF SPOT DISEASE OF *POTHOS SCANDENS* (WALL).

By

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Leaf spot diseases caused by fungi are of wide occurrence and have been reported practically from every part of the world. About 60% plants suffer with such diseases. Organisms responsible for these diseases not only disfigure the host but they considerably reduce the photosynthetic area of the host, which ultimately causes great loss in the manufacture of the organic food. Repeated loss of the foliage may even result in the death of the plant. A search through the available literature shows that they have not been studied in detail and generally only the symptoms of such diseases have been recorded.

Several species of *Colletotrichum* causing leaf spot disease have been reported from India. Some of the species are pathogenic on the plants of economic importance viz., *C. falcatum* on *Saccharum officinarum* (Kulkarni, 1911), *C. graminicolum* and *C. catechue* on *Andropogan sorghum* and *Areca catechue* respectively (Sydow and Butler, 1916), *C. zingiberia* on *Zingiber officinale* (Sundaraman, 1923), *C. indicum* on *Gossypium* sp. (Dastoor, 1934), *C. hibisci* on *Hibiscus esculentus* (Uppal *et al.*, 1935), *C. falcatum var arundinis* on *Arundo donax* (Rama Krishnan 1949), *C. ciliatum* on *Cympogon polyneures* (Rama Krishnan and Rama Krishnan, 1947), *C. capsici* f. *cyamopsicola* on *Cyamopsis* (Desai and Prasad, 1955). *C. capsici* on *Capsicum annum* (Chawdhury, 1957) and *C. spinaceae* on *Spicacia oleracea* (Singh and Gupta, 1951). Some ornamental plants like *Dracaena* (*C. dracaena fragrantis*, Sydow and Mitter, 1937), and *Agave rigida* (*C. agava*, Butler, 1918) are also attacked by species of *Colletotrichum*.

The leaf spot disease of *Pothos scandens* has not been reported from India so far. It was, therefore, decided to undertake the physiological and pathological studies of the organism responsible for the disease. The details of the pathological studies have been included in the present paper.

MATERIALS AND METHODS

The present organism was isolated from the infected leaves of *Pothos scandens*. The methods of isolation, purification and subculturing were similar to those of Tandon & Bilgrami (1954). Artificial inoculation of *C. capsici* were tried on the different parts of the host. Pathogenicity tests were conducted on injured as well as uninjured surfaces. The surfaces were sterilized with 90% alcohol or 0·1% mercuric chloride. The leaf surfaces were then thoroughly washed with sterilized water. Injury whenever necessary was inflicted with the help of sterilized needle and every possible care was taken to avoid deep injury. Reisolations were always made to confirm the results. The following different methods of inoculation were tried for inoculating the leaves.

(*i*) *Mass inoculation method* :—Small piece of inoculum containing both spores and mycelium was placed on the injured or uninjured surface of the leaf by means of a sterilized needle and the inoculated area was covered with a moist cotton pad.

(*i*) *Spore suspension method* :—A suspension of spore in sterilized water was sprayed with an automizer on the uninjured or injured surfaces of the leaves. Moist cotton pads were also used.

Cross inoculations were carried out on different hosts. Various fungicides were evaluated in the laboratory by the method described by Fosberg (1949) and the successful ones were then applied to the plants. The leaves of the plants were dusted with different fungicides both before and after inoculation. Ridgway's "Color Standards and Color Nomenclature" was used for determination of colours.

SYMPTOMS

Under natural condition only the leaves of *Pothos scandens* were infected. The attack starts after the new leaves appear. The first indication of the disease is the appearance of yellow minute spot which soon becomes brown. In the early stage the spots are minute but their size increases with age. They may be oval, elliptical or circular (*vide* Fig. 1) in shape. The infected tissues dry up and collapse causing a depression in the centre of the spot. The affected and the healthy portions of the leaf are clearly separated by a yellow brown band. Some times two or more spots form irregular lesions involving the entire leaf. Black dot like bodies (which are acervuli of the fungus) appear on the upper surface of the affected area. The acervuli are mostly formed near the margin and are generally arranged in concentric rings. The number of acervuli depends on the prevailing humidity and temperature of the atmosphere. The acervuli are carbonaceous in colour.

MORPHOLOGY OF THE FUNGUS

(*a*) *Morphological characters of the fungus on the host* :—The hyphae are branched, hyaline and septate. Spores are formed inside the acervuli. They are unicelled, hyaline and elongated with blunt ends. The average size of the spore is 30 $\times$ 3·3 μ. The size of the acervuli varies from 236 μ to 267 μ. The setae are septate and their size ranges from 73 μ to 95 μ.

(*b*) *Morphological characters of the fungus on different media* :—The fungus was grown on a number of media to study its morphology. The dry weight, spore size, size of the setae etc. on liquid media are given in Table I.

TABLE I

Showing the dry weight, spore size and size of the setae on different media.

	Media	Spore size in μ	Size of Setae in μ	Dry wt. in mg.	Sporulation
1.	Richard's Medium	32 $\times$ 3·3	75	265	Excellent
2.	Potato Dextrose	30 $\times$ 3·3	96	185	Excellent
3.	Brown's Medium	33 $\times$ 3·3	75	86	Fair
4.	Asthana & Hawkers Medium 'A'	26 $\times$ 3·3	73	75	Good
5.	Coon's Medium	33 $\times$ 3·3	73	46	Fair
6.	Leaf extract	—	—	39	—

It is obvious from the table that Richards and Potato dextrose agar were best for growth and sporulation of the organism. The size of the spore ranged between 26·3 × 3·3 μ to 33·3 × 3·3 μ. It was largest in Coon's and Brown's medium and smallest in Asthana and Hawker's medium. The mycelia of the young cultures were subaerial, thin, septate, cottony white to pinkish in colour. It may be pointed out that the range of variation noticed on different media is commonly observed on the host and it is, therefore, not desirable to place any significance on these differences.

Artificial inoculation :—The organism was inoculated on the leaves of *Pothos scandens* by mass inoculation and spore suspension method. It was noticed that all the injured leaves were infected within 3—5 days by the mass inoculation method. The percentage infection was similar on both the surfaces of the leaf. The organism was incapable of causing any infection on the old leaves even from the lower surface without any injury. Only 20% of the young leaves were, however, infected when the inoculum was placed on the lower surface near the tips of the young leaves. It was further observed that the percentage of infection was smaller when the spore suspension method was used. The percentage of infection was only 80%.

Cross inoculation :—The present organism was inoculated on leaves and fruits of the following plants, from which some species of *Colletotrichum* have been reported. The results are given in Table 2.

TABLE 2

Showing the result of cross inoculation on leaves and fruits of various plants.

Name of the different host.	Leaf or Fruit	% infection
1. *Dracaena* sp.	Leaf-Upper Surface	100
	Lower surface	100
2. *Acalypha indica*	Leaf-Upper surface	60
	Lower surface	60
3. *Musa paradisiaea*	Fruit-old	0
4. *Carica papaya*	Fruit-old	0
5. *Capsicum annum*	Fruit-Young	100
	old	100
6. *Lycopersicum esculentum*	Fruit-Young	100
	old	100

The above table indicates that the cross inoculation was successful on *Dracaena* sp., *Acalypha indica*, *Capsicum annum* and *Lycopersicum esculentum* but it could not infect the fruits of *Carica papaya* and *Musa paradisiaea*. The fruits of *Capsicum annum* (vide Fig. 2) and *Lycopersicum esculentum* (vide Fig. 3) were very susceptible. Occasionally on these two hosts the acervuli were densely aggregated all over the infected parts. They projected little above the surface of the fruit and were carbonaceous in colour.

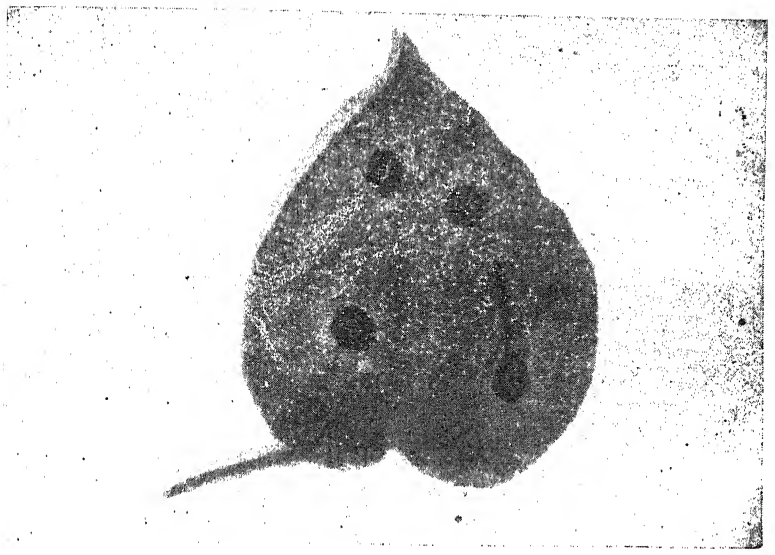

Fig. 1. Showing the circular infected spot on the leaves of *Pothos scandens*.

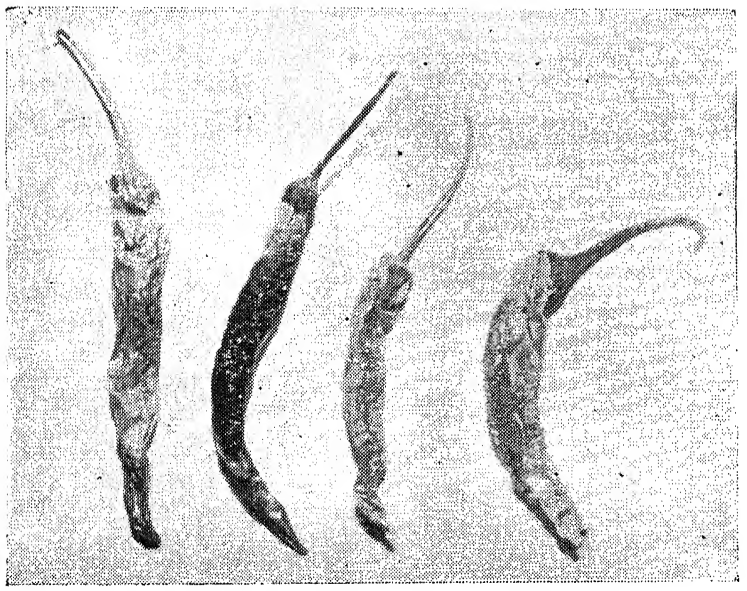

Fig. 2. Showing the infection of various intensities produced on the fruits of *Capsicum annum*. Black acervuli are distinctly visible over some of the lesions.

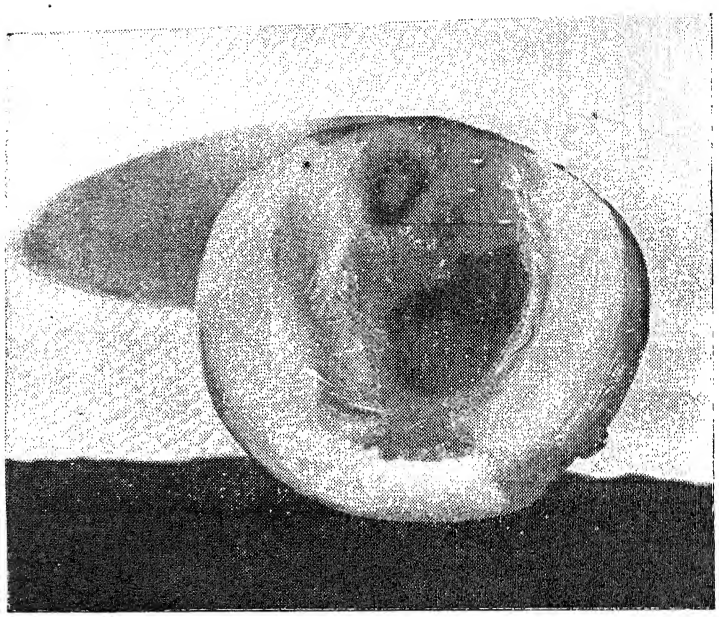

Fig. 3. Showing the infection over the mature fruit of *Lycopersicum esculentum*.

Fig. 4*a*. Showing the effect of spraying zerlate after inoculation—the leaf of the host showing very slight infection after 15 days of inoculation.

Fig. 4*b*. Infection produced after 15 days of inoculation—No fungicide was sprayed.

CONTROL MEASURES

(*i*) *Effect of volatile substances* :—Volatile substances are known to inhibit the growth of many fungi and they can, therefore, be used in controlling the disease. The following volatile substances *viz.*, acetic acid, ammonia, absolute alcohol, benzene, chloroform, formaline, carbon tetra-chloride and ether were used for studying their effect on the growth of the organism. It was found that there was no growth in any case. The inoculum was transferred to tubes containing Asthana and Hawker's medium 'A'. This was done to remove the inoculum from the direct influence of the vapour but no growth was recorded. It was thus clear that the organism was killed by the vapours of all the volatile compounds used in the present investigation.

(*b*) *By fungicides* :—Ten fungicides were evaluated in the laboratory. They included, bordeaux mixture 5:5:50, zerlate, phygon, cuprovit, copper sandoz, cereson, tillex, diathane, D. 14 and spergon. It was found that phygon, cereson, tillex, spergon, zerlate and D. 14 inhibited the growth of the organism while bordeaux mixture, diathane, copper sandoz and curprovit did not have any effect.

For the field experiment only tillex; cuprovit, copper sandoz, zerlate, and phygon were used. The fungicides were dusted on the leaves of the host, at various intervals both before and after artificial inoculation. The results are summarized in Table 3.

TABLE 3

Showing the effect of different fungicides dusted on the leaves of *Pothos scandens* inoculated with *C. capsici*, + and - have been used to denote the appearance or absence of disease respectively.

Time of inoculation	Phygon	Tillex	Cuprovit	Copper Sandoz	Zerlate
1. Just after dusting	-	-	-	-	-
2. 1 day ,, ,,	-	-	-	-	-
3. 2 days ,, ,,	-	-	-	-	-
4. 3 days ,, ,,	+	+	+	+	-
5. 4 days ,, ,,	+	+	+	+	-
6. 7 days ,, ,,	+	+	+	+	-
7. Just before dusting	-	-	-	-	-
8. 1 day ,, ,,	-	-	-	-	-
9. 2 days ,, ,,	-	-	-	-	-
10. 3 days ,, ,,	+	+	+	+	-
11. 4 days ,, ,,	+	+	+	+	-
12. 7 days ,, ,,	+	+	+	+	-

It is evident from the above table that zerlate was the most effective fungicide when it was dusted one week before or after artificial inoculation (vide Fig. 4). The remaining fungicides *viz.*, phygon, tillex, cuprovit, and copper sandoz were not so suitable as they were ineffective if they were not dusted within 2 days of inoculation.

DISCUSSION

Species of *Colletotrichum* are known to cause diseases on various plants. *Pothos scandens* is a plant of ornamental value. The present results have shown that *C. capsici* (isolated from *Pothos scandens*) not only caused damage to its host but it could also cause considerable infection on other plants of economic importance *viz.*, *Lycopersicum esculentum* and *Capsicum annum*.

Mass inoculation method was found to be most successful. Tandon and Bilgrami (1954), Tandon *et al* (1955) and Bilgrami (1956) have also reported this method to be more effective than others. Mostly the infection could take place only to the injured surface of the leaf but infection was also possible from uninjured tips of young leaves. This indicates that the young leaves are more susceptible to the disease than the older ones. Tandon and Bilgrami (1954, 1955, 1957) who have studied several leaf spot diseases have also reported that there was little infection through uninjured tissues. The organism is not very specialized in its parasitic activity as it can easily infect the leaves of *Dracaena* sp., *Acalypha indica* and the fruits of *Lycopersicum esculentum* and *Capsicum annum*. The spread of disease was much faster on the fruits than on the leaves. The acervuli were only formed on the fruits of *Lycopersicum esculentum* and *Capsicum annum* and they were not produced on the leaves of *Dracaena* sp. and *Acalypha indica*. Six out of the 10 fungicides used could check the growth of the organism in laboratory but only one of them *viz.*, zeralate was found to be effective and that too could control the disease when it was dusted only a week before or after the artificial inoculation. In nature it is not possible to know the exact time when the organism will infect the host tissue and it will, therefore, be necessary to work out the number of application which will be needed to control the disease.

Chowdhury (1957) reported that *C. capsici* isolated from *Capsicum annum* was incapable of infecting the young fruits of chillies. It is interesting because the present organism (viz., *C. capici* isolated from *Pothos scandens*) was capable of causing infection on both young as well as old fruits of *Capsicum annum*. This suggests that *Colletotrichum capsici* on *Capsicum annum* and *C. capsici* on *Pothos scandens*, may be two different strains of the same species.

SUMMARY

Collectotrichum capsici was found to be pathogenic on the leaves of *Pothos scandens*. Cross inoculations were made and it was found that it could infect the leaves of *Dracaena* sp. and *Acalypha indica* and the fruits of *Capsicum annum* and *Lycopersicum esculentum*. Laboratory evaluation of fungicides showed that phygon, cereson, tillex, spergon, zerlate, and D. 14 could inhibit the growth of the organism. Besides these, a number of other volatile substances were also found to be toxic to the organism. The disease could be controlled in the field by the application of zerlate.

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NITROGEN REQUIREMENTS OF SOME SPHAEROPSIDALES

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INTRODUCTION

The importance of nitrogen in the nutrient medium for the growth of the fungi has long been recognised. On the basis of the ability to utilize different sources of nitrogen Robbins (1937) and Steinberg (1939) classified fungi into various groups. It is well established that one particular source of nitrogen can not be similarly utilized by all the fungi. In Sphaeropsidales Allison, Horr and Morris (1934), Robbins (1937), Hawker (1950. pp. 61), Mix (1953) and Tandon and Bilgrami (1955) have reported different patterns of utilization of various nitrogen compounds by *Phoma* sp., *Diplodia zeae*, some species of *Phoma*, *Phyllosticta solitaria* and *Phyllosticta cycadina* respectively.

Out of the vast number of organic compounds, which contain nitrogen, those which occur naturally are of interest in fungal nutrition. Amino acids, which are the ultimate products of protein hydrolysis occur free in many plants and have been isolated from proteins. Leonian and Lilly (1940) and Bilgrami (1956) studied the growth of their respective fungi in single amino acids and their mixture.

The physiological specificity between two genera of the same family (Bhargava, 1945) and two closely allied species of the same genus (Norkans, 1950 and Tandon and Grewal, 1956) have long been established.

It was, therefore, thought desirable to study the nitrogen nutrition of following species of Sphaeropsidales.

1. *Botryodiplodia* sp.
2. *Botryodiplodia theobromae* Pat.
3. *Diplodia cajani* Ray Chaudhuri.
4. *Macrophomina Phaseoli* (Maubl.) Ashby.

MATERIAL AND METHODS

Cultures of *Botryodiplodia theobromae* Pat. and *Diplodia cajani* Raychaudhuri were provided by the Head of the Mycology Section, I. A. R. I., New Delhi, while those of *Botryodiplodia* sp. and *Macrophomina phaseoli* (Maubl) Ashby by Dr. J. C. Edward, Agriculture Institute, Naini (Allahabad). The experiment was conducted in two parts. In the first asparagine of the basal medium (Glucose, 5·0 gms; K_2HPO_4, 0·5 gms; $MgsO_4$, $7H_2O$, 0·5 gms and double distilled water, 1000 cc) was replaced by 13 different sources of nitrogen singly, *e.g.*, nitrate, nitrite and ammonium nitrogen from inorganic sources and monoamino mono carboxylic acids, monoamino dicarboxylic acids, basic amino acids and amines from organic sources, so as to furnish 400 mg/litre of nitrogen. 25 ml. of sterilized media were poured in each of 150 cc. Erlenmyer Pyrex flasks which were inoculated with 4 days old cultures of the organisms. After incubating the flasks for 15 days at room temperature (mean 24°C) the contents were filtered off and dry weight of mycelium was taken after drying for 2 days at 65°C in weighed filter papers. Only average dry weights of fungal colonies in three replicates, on different sources, were tabulated. The results, thus recorded, were statistically analysed and classifie dinto good, moderate and poor. In the second part a chromatographic study of assimilation of four different amino acids in a mixture along with their relative growth supporting values was undertaken. The flasks were daily inoculated with different fungi approximately at the same time (± 15 minutes) during a period of 10 days at the room temperature (mean 24°C). Dry weight of fungal mats was taken as usual. The filterate in each case was used for the chromatographic analysis by the method described by Ranjan *et al* (1955) and used by Tandon and Bilgrami (1957) and Raizada (1957). Whatman filter paper No. 1 was used. *n*-Butanol : acetic acid: water in the ratio of 4 : 1 :5 was used as developing solvant while chromatograms were sprayed with 0·1% *n*-ninhydrin in normal butanol. After drying for 3-4 hours at room temperature they were heated in an electric oven at 90°C for five minutes.

Chemical substances of high grade purity were used. Glassware was thoroughly washed with hot double distilled water before the commencement of the exepriment.

EXPERIMENTAL

The results of dry weight and sporulation obtained on different nitrogen sources for *Botryodiplodia* sp., *Botryodiplodia theobromae*, *Diplodia cajani* and *Macrophomina phaseoli* are present in table 1.

TABLE 1

Average dry weight in mgs. and sporulation of *Botryodiplodia* sp., *Botryodipladia theobromae*, *Diplodia cajani* and *Macrophomina phaseoli* on different nitrogen sources.

Nitrogen source	*Botryodiplodia* sp.		*B. theobromae*		*D. cajani*		*M. phaseoli*	
	Dry wt. in mgs.	Sporulation	Dry wt. in mgs.	Sporulation	Dry wt. in mgs.	Sporulation	Dry wt. in mgs.	Sporulation
1. Ammonium nitrate ...	33	...	33	...	22	...	35	...
2. Ammonium chloride	18	...	16	...	37	...	29	...
3. Potassium nitrate ...	51	Excellent	15	...	24	...	33	...
4. Sodium nitrite ...	26	...	4	...	4	...	12	...
5. Glycine ...	22	Excellent	14	...	13	...	25	...
6. Valine ...	32	...	28	...	21	...	49	...
7. Glutamic acid ...	31	...	3	...	6	...	24	...
8. Asparagine ...	41	...	27	...	23	...	43	...
9. Alanine ...	46	...	25	...	65	...	45	...
10. Tyrosine ...	35	Good	24	...	32	...	52	...
11. Histidine ...	64	...	31	...	41	...	26	...
12. Cystine ...	45	Fair	4	...	1	...	17	...
13. Thio-urea ...	5	...	9	...	29	...	4	...
14. Control ...	0	...	0	...	0	...	0	...
	Average 32·07		Average 17·07		Average 22·63		Average 28·28	

For statistical calculations the results of an individual organism on different sources of nitrogen were compared.

Summary of dry weight results and conclusions at 1% level of *P* for *Botryodiplodia* sp.

Treatments	– Highly significant
Replicates	– Non-significant
S. E.	– 0·541
C. D. at 1% level	– ± 2·119

Dry weight results :

Nitrogen compounds
Dry weight in mgs.

Histidine 64 > Pot. nitrate 51 > Alanine 46, Cystine 45 >

Asparagine 42 > Tyrosine 35, Amm. nitrate 33 > Valine 32 > Glutamic acid 31 >

Sod. nitrite 26 > Glycine 22 > Amm. chloride 18 > Thio-urea 5 > Control 0

Summary of the dry weight results and conclusions at 1% level of *P* for *Botryodiplodia theobromae*.

Treatments	– Highly significant
Replicates	– Non-significant
S. E.	– 0·589
C. D. at 1% level	– ± 2·30

Dry weight results :

Nitrogen compounds
Dry weight in mgs.

Amm. Nitrate 33, Histidine 31 > Valine 27, Asparagine 27

Alanine 25, Tyrosine 24 > Amm. chloride 16, Pot. nitrate 15, Glycine 14 >

Thiourea 9 > Cystine 4, Sod. nitrite 4, Glutamic acid 3 > Control 0

Summary of the dry weight results and conclusions at 1% level of *P* for *Diplodia cajani*.

Treatments	– Highly significant
Replicates	– Non-significant
S. E.	– 0·578
C. D. at 1% level	– ± 2·264

Dry weight results :

Nitrogen compounds
Dry weight in mgs.

Alanine 65 > Histidine 41 > Amm. chloride 37 > Tyrosine 32 >

Thio urea 29 > Pot. nitrate 24, Asparagine 23, Amm. nitrate 22, Valine 21 >

Glycine 13 > Glutamic acid 6, Sod. nitrite 4 > Cystine 1 > Control 0

Summary of the dry weight results and conclusions at 1% level of *P* for *Macrophomina phaseoli*.

Treatments	– Highly significant.
Replicates	– Non-significant.
S. E.	– 0·413
C. D. at 1% level	– ± 1·618

Dry weight results:

Nitrogen compounds Dry weight in mgs.

Tyrosine 52 > Valine 49 > Alanine 45 > Asparagine 43 > Amm. nitrate 35 > Pot. nitrate 33 > Amm. chloride 29 > Histidine 26, Glycine 25, Glutamic acid 24 > Cystine 17 > Sodium nitrite 12 > Thio urea 4 > Control 0

A critical review of table 1 shows that these fungi were unable to grow in the absence of any source of nitrogen. Ammonium nitrate was good for the growth of *Botryodiplodia theobromae* and *Macrophomina phaseoli* while for the rest it was only moderate. Ammonium chloride, the only ammonium source of nitrogen taken in the present study, supported good growth of *Diplodia cajani*, moderate of *Botryodiplodia theobromae* and *Macrophomina phaseoli*, and poor of *Botryodiplodia* sp. For the growth of *Botryodiplodia* sp. and *Macrophomina phaseoli* potassium nitrate was a good source and for the rest of the organisms it was moderate. Sodium nitrite was a poor source for all the fungi under investigation.

Alanine was a good source for all the four fungi while glycine was poor for all of them. Valine was a good source for *Botryodiplodia theobromae* and *Macrophomina phaseoli* but it was moderate for the rest.

Glutamic acid supported poor growth of all the fungi excepting *Botryodiplodia* sp. for which it was only moderate. Asparagine, on the other hand, supported good growth of all the fungi except of *Diplodia cajani* in which case it gave moderate growth. Tyrosine and histidine were good sources for all the fungi, except for the fact that the latter was poor for *Macrophomina phaseoli*. Cystine was of no value for any of the organisms except *Botryodiplodia* sp. which developed good growth. Thio-urea was a good source for *Diplodia cajani* while it was a poor source for others.

Assimilation rate of mixture of amino acids :

The amino acids, *viz.*, histidine (Rf 0·54), glycine (Rf 0·62), glutamic acid (Rf 0·66) and alanine (Rf 0·75) were used in a mixture. The results are summarized in Table 2.

TABLE 2

Showing the presence of amino acids, change in the pH of the medium and the daily dry weight in the case of four fungi under study.

	DAYS									
	1	2	3	4	5	6	7	8	9	10
1. *Botryodiplodia* sp.										
Presence of Histidine	+	+	+	+	—	—	—	—	—	—
Presence of Glycine	+	+	+	+	+	+	+	+	+	—
Presence of Glutamic acid	+	+	+	+	+	+	+	+	+	+
Presence of Alanine	+	+	+	+	+	+	+	+	+	+
Dry weight in mgs.	4·2	7·3	16·5	28·1	43·0	58·6	69·9	73·2	81·0	89·2
pH	6·0	5·8	5·5	5·5	5·6	5·8	7·0	7·3	7·3	7·9
2. *Botryodiplodia theobromae.*										
Presence of Histidine	+	+	+	—	—	—	—	—	—	—
Presence of Glycine	+	+	+	+	+	+	+	+	—	—
Presence of Glutamic acid	+	+	+	+	+	+	+	+	+	+
Presence of Alanine	+	+	+	+	+	+	+	+	+	+
Dry weight in mgs.	1·9	4·3	12·8	24·0	39·6	47·1	55·2	62·3	66·7	72·3
pH	6·2	5·8	5·4	5·3	5·6	6·5	7·4	8·0	8·4	8·4
3. *Diplodia cajani.*										
Presence of Histidine	+	+	+	+	—	—	—	—	—	—
Presence of Glycine	+	+	+	+	+	+	+	—	—	—
Presence of Glutamic acid	+	+	+	+	+	+	+	—	—	—
Presence of Alanine	+	+	+	+	+	+	+	—	—	—
Dry weight in mgs.	2·3	6·9	19·2	31·3	49·5	53·2	62·1	71·3	78·5	88·8
pH	6·1	5·8	5·5	5·5	5·5	7·9	8·3	8·4	8·4	8·6
4. *Macrophomina phaseoli.*										
Presence of Histidine	+	+	+	+	+	+	—	—	—	—
Presence of Glycine	+	+	+	+	+	+	+	+	+	+
Presence of Glutamic acid	+	+	+	+	+	+	+	+	+	+
Presence of Alanine	+	+	+	+	+	+	+	+	+	+
Dry weight in mgs.	3·9	9·2	21·8	38·2	45·6	52·8	59·6	65·1	71·2	75·3
pH	6·4	5·8	5·6	5·6	5·6	5·5	5·5	6·8	7·0	7·9

\+ indicates the presence

— indicates the absence

As indicated in table 2 all the fungi utilized the mixture of amino acids well, it being better than the individual amino acids (Cf Table 1). All the four organisms preferred histidine for their utilization. They first lowered the pH of the medium which then drifted to a higher range and became alkaline by the end of the incubation period. The rate of growth of all the fungi continued to increase till the end of the incubation period. After its rapid increase during the first few days it slowed down. The mixture could not be utilized completely within the specified time by other fungi except *Diplodia cajani*.

DISCUSSION

Since the fungi used in present study are unable to grow on a synthetic medium lacking nitrogen, it is evident that nitrogen is essential for the growth of these organisms.

The favourable utilization of ammonium nitrate by *Botryodiplodia theobromae* and *Macrophomina phaseoli* finds support from the work of Saksena (1940) on some species of *Pythium*, Raizada (1957) on some *Mucorales* and Verma (1957) on *Pestalotia* sp. and *Phyllosticta* sp. These results, however, are in contradiction with those reported by Mix (1933) for *Phyllostieta solitaria*, Patel *et al* (1950) for *Pestalotia psidii*, Tandon (1950) for *Pestalotia malorum* and Bilgrami (1956) for *Phyllosticta artocarpina* and *P. cycadina*, who had reported that ammonium nitrate to be a poor source for their fungi.

The behaviour of *Diplodia cajani* was similar to that of fungi investigated by Bhargava (1945) and Mehrotra (1949) who reported favourable utilization of ammonium chloride. *Botryodiplodia* sp., however, resembled *Taphrina americana* (Mix, 1935), *Fusarium vasinfectum* (Subramaniam and Srinivaspai, 1953) and two species of *Phyllosticta* (Bilgrami, 1956) in poor utilization of this nitrogen source.

Good utilization of nitrate nitrogen (given in the form of potassium nitrate) by *Botryodiplodia* sp. and *Macrophomina phaseoli* finds support from the results obtained by Neal *et al* (1935), Grewal (1954) and Bilgrami (1956) for the organisms studied by them. In the present studies nitrate nitrogen proved to be better than ammonium nitrogen for the growth of *Botryodiplodia* sp. and *Macrophomina phaseoli*. In this respect these fungi resembled *Phytophthora megasperma* (Lopatecki and Newton, 1956). *Botryodiplodia theobromae* and *Diplodia cajani* on the other hand, resembled *Phytophthora cactorum* and *Phytophthora parasitica* (Lopatecki and Newton, l. c.), where ammonium nitrogen was better utilized for their growth than nitrate nitrogen.

Sodium nitrite was a poor source for all the fungi investigated and in this respect the results were similar to those of Gordon (1950), Patel *et al* (1950) and Tandon and Bilgrami (1957). *Blakeslea trispora* (Leonian and Lilly, 1938), *Morchella esculenta* (Brock, 1951) and *Hormodendrum resinae* (Morsden, 1954), however, differed from the fungi under investigation as they could grow on nitrites.

Foster (1949, p. 493) observed that virtually all the fungi grew faster and probably more abundantly with complex organic materials as the source of nitrogen than with simple inorganic nitrogen. The non-utilization of glycine by the fungi employed in the present studies finds support from the results of Gottleib (1940) for *Fusarium oxysporum* and *Helminthosporium gramineum*, Bilgrami (1956) for two species of *Phyllosticta* and Verma (1957) for *Phyllosticta* sp. *Botryodiplodia theobromae* and *Macrophomina phaseoli* could be compared with organisms studied by Tandon (1950), Wolf (1953), Srivastava (1955) and Bilgrami (1956) which utilized Dl. Valine as a

favourable source for their growth. Alanine supported good growth of all the fungi. This result is in agreement with those obtained for *Aspergillus niger* (Steinberg, (1942) and *Choanephora cucurbitarum* (Lilly and Barnett, 1951).

The present observations regarding the poor utilization of glutamic acid by *Botryodiplodia theobromae, Diplodia cajani* and *Macrophomina phaseoli* are not in agreement with those reported by Tondon (1950) for *Pestalotia malorum,* Grewal (1954) for *Gloeosporium musarum* and Bilgrami (1956) for *Phyllosticta* species and *Pestalotia mangiferae.* The favourable utilization of asparagine by all the fungi except *Diplodia cajani* supports the results obtained by Patel *et al* (1950) Brock (1951) and Bilgrami (1956) for their respective fungi. Tyrosine supported good growth of all the fungi under investigation and these results are in agreement with those obtained for *Pestalotia malorum* and *Pestalotia psidii* (Tandon, 1950) and *Phyllosticta cycadina* (Bilgrami, 1956). The behaviour of all the fungi except *Macrophomina phaseoli* was similar to that of *Phyllosticta cycadina* (Bilgrami l. c.) which utilized histidine favourably. *Macrophomina phaseoli,* on the other hand, could be classed with *Ustilago zeae* (Wolf, 1953) *Phyllosticta artocarpina* (Bilgrami, 1956) and some *Mucorales* (Raizada, 1957) for the poor utilization of this amino acid.

Cystine supported poor growth of all organisms except *Botryodiplodia* sp. of which it gave good growth. Thio urea was a poor source for all the fungi except *Diplodia cajani* These results are similar to those obtained by Brock (1951) for *Morchella esculenta* Grewal (1954) for *Gloeosporium papayae* and Bilgrami (1956) for *Pestalotia mangiferae. Diplodia cajani,* however, differed from these organisms because of its good growth on this organic compound.

A comparative study of the results recorded in Table 2 with those in table 1 shows that all the fungi make better growth on the mixture of amino acids than on a single one. Similar results were obtained by Leonian and Lilly (1940) for *Phycomyces blackesleeanus,* Bilgrami (1950) for *Phyllosticta cycadina* and *P. artocarpina* and Raizada (1957) for some *Mucorales. Diplodia cajani* resembled with the fung investigated by Bilgrami (1. c.) in consuming the mixture of amino acids within the specified period.

Alanine proved to be a good source for the growth of present organisms, when it was provided alone but it was not utilized by these fungi from the mixtur except by *Diplodia cajani.* On the other hand, glycine, which was a poor source when supplied singly, was consumed by *Botryodiplodia* sp., *Botryodiplodia theobromae* and *Diplodia cajani* on 9th, 10th and 8th day respectively. Histidine, which was a poor source for the growth of *Macrophomina phaseoli* was utilized completely by this fungus by the 7th day. This behaviour of the present fungi can be interpreted by the fact that "all primary amino acids are not similar for the same fungus and the effect of one amino acid on the utilization of another varies (Lilly and Barnett, 1951 pp. 105 and 106)".

According to Butkewitsch (1903) and Tamiya and Usami (1940) utilization of amino acid nitrogen is preceeded by deamination. Deamination or assimilation, in fact, according to Steinberg (1942) preceeds most readily with the first formed amino acids since they are fully equivalent to inorganic nitrogen. It has also been mentioned by Lilly and Barnett, (1951, p. 108) that during the process of deamination, nitrogen in the form of ammonia is released which is utilized by most of the fungi. Saksena *et al* (1952) reported that 13 species of *Pythium* changed the pH of the medium containing alanine, asparagine, glutamic acid and glycine towards alkaline range. They concluded that ammonia was formed and accumulated in the media

containing various amino acids and this accumulated ammonia was the cause of eventual rise in the pH of the media. In the present studies, due to early utilization of ammonia, the pH of the media on which the fungi were growing showed a decrease which was eventually raised by accumulation of excess of ammonia.

SUMMARY

The nitrogen requirements of *Botryodiplodia* sp., *Botryodiplodia theobromae*, *Diplodia cajani* and *Macrophomina phaseoli* were studied under controlled conditions. Out of the inorganic sources, ammonium nitrate was a good source for the growth of *Botryodiplodia theobromae* and *Macrophomina phaseoli* and for the rest it was moderate. Only *Diplodia cajani* utilized ammonium nitrogen favourably (NH_4Cl being the source), while *Macrophomina phaseoli* and *Botryodiplodia theobromae* could use it only moderately. Potassium nitrate was good only for *Botryodiplodia* sp. and *Macrophomina phaseoli* only. Sodium nitrite was a poor source for all. Amongst the organic sources alanine and glycine were good and poor respectively for all the fungi under investigation. Valine could support good growth of *Botryodiplodia theobromae* and *Macrophomina phaseoli* only. Asparagine supported good growth of the majority of these fungi. Tyrosine was found to be good for all the fungi employed. Histidine was a good source for all expect *Macrophomina phaseoli*. Cystine was a poor source for all except *Botryodiplodia* sp. for which it was good. Thio-urea supported good growth of *Diplodia cajani* though it was poor for the rest.

Chromatographic analysis of mixture of four amino acids, viz., histidine, glycine, glutamic acid and alanine showed selective utilization of these amino acids by the four fungi. Except *Diplodia cajani* all the fungi utilized histidine earlier than any other amino acid from the mixture. Subsequently *Botryodiplodia* sp. and *B. theobromae* finished glycine also on 9th and 10th day respectively. *Diplodia cajani* finished the whole mixture by 7th day. It is assumed that fungi assimilated ammonia during early stages of growth (thus showing fall in pH of media), but later on account of its accumulation the pH of the media was raised.

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KEY TO THE ORIENTAL SPECIES OF *APANTELES* FÖRSTER (HYMENOPTERA)

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Apanteles Förster (1862) was not well known from the Oriental Region, until very recent times. Szeplegete (1904) recorded four species only as belonging to this genus, in the beginning of the current centuary. Cameron (1891) described *flavipes* under the genus *Cotesia*, which probably happens to be the first species, now included in *Apanteles*. Later, Cameron himself, and Bingham, Vierick and Wilkinson described a large number of new species from India. Lal, Madihassian and Bhatnagar are the notable recent workers who described a large number of Oriental species.

I was engaged in the study of the species belonging to this genus in identifying the material received from various sources, for the last twelve years. During this period much material and matter has accumilated and a suitable key for the identification of the species was very much needed. I have tried this key for my personal work and found it to be very helpful and suitable in the identification. In the majority of cases type-specimens were studied and in a few cases, where such material was not available, original descriptions were consulted. In the absence of any suitable key, this will be very helpful for identifications. The first reference of the species and its known distribution is also added to make the key more useful.

I am thankful to the various authorities who assisted and helped me in the collection of the required information in the preparation of this paper.

1. Propodeum usually with an areola; second tergite shorter than third ... 2

   Propodeum always without an areola; second tergite as long as third ... 55

2. Propodeum with costulae ... 3

   Propodeum without costulae ... 36

3. Scutellum and mesonotum strongly and rugosely punctate ... 4

   Scutellum not rugosely punctate, at least not as strongly as mesonotum ... 6

4. Vein R_1 longer than pterostigma ... 5

   Vein R_1 as long as pterostigma; length of vein r less than the breadth of pterostigma. (*Indian J. Ent.*, **10**: 172, 1948, Dhulia-Bombay). ... *jhaverii* Bhatnagar

5. Length of vein *r* equal to or only slightly greater than the breadth of pterostigma. (*Indian J. Ent.*, **12**: 7, 1950, Agra) ... *valvulae* Rao & Kurian

Length of vein *r* distinctly greater than the breadth of pterostigma. (*Ann. Mag. nat., Hist.*, **5**: 308, 1860, Ceylon, New Delhi) ... *significans* (Walker)

6. Flagellum in ♀ with a pale band. (*Bull. ent. Res.*, **19**: 109, 1928, Java) ... *taeniaticornis* Wilkinson

Flagellum in ♀ without such a band ... 7

7. Hind femora of ♀ reddish-brown, brown, nigrescent or partly or wholly black, at least in part darker than the basal portion of hind tibiae ... 8

Hind femora of ♀ wholly clear red or red yellowish-brown, never in any part darker than the basal portion of the hind tibiae ... 22

8. Tegulae black ... 9

Tegulae clear testaceous, red testaceous or red-yellowish-testaceous ; areola closed at base; mesonotum strongly punctate; length of apical tergite thrice its apical width. (*Indian J. Ent.*, **12**: 15, 1950, Agra) ... *longitangiae* R. and K.

9. Pterostigma in ♀ hyaline, narrowly margined with pigmentation ... 10

Pterostigma in ♀ uniformly opaque or with very faint cloud at extreme base, at-most upto basal one-fourth ... 12

10. Mesonotum in part rugose or rugosely striate, sepecially posteriorly ... 11

Mesonotum not rugose any where, smooth and shiny posteriorly. (*Bull. ent. Res.*, **21**: 280, 1930, Malaya) ... *haoris* Wilkinson

11. Propodeum smooth except for areola and costulae. (*Indian J. Ent.*, **10** : 175, 1948, Travancore) ... *ricinii* Bhatnagar

Propodeum rugose, scutellum smooth and shiny. (*Proc. U. S. Nat.* Mus., **42** : 140, 1912, Bangalore) ... *taragamae* Vierieck

12. Pterostigma in ♂ hyaline and narrowly margined with pigmentation ; areola and costulae very strong and the former V-shaped at apex and more or less closed at base ; first tergite

with a strong median rugose tumescence; scutellum with numerous strong punctae. (*J. N. Y. ent. Soc.*, 12 : 18, 1904, Manila) ... *opacus* Ashmead

Pterostigma in ♂ as in ♀ ... 13

13. Scape testaceous; ovipositor sheath as long as or longer than the hind femora; second tergite smooth except for some obscure punctae ... 14

Scape black, not at all testaceous ... 16

14. Second abdominal suture straight; vein *r* distinctly longer than and angled with vein *r-m*. (*Treubia*, 3 : 54, 1922, Manila) ... *parasae* Rhower

Second abdominal suture curved at least in ♀... 15

15. Vein *r* not distinctly angled with *r-m*; ovipositor stout; length of second tergite less than half the apical breadth of the first tergite. (*Bull. ent. Res.*, 19 : 133, 1928, Java) ... *hasorae* Wilkinson

Vein *r* distinctly angled with *r-m*; ovipositor slender. (*Bull. ent. Res.*, 19 : 134, 1928, Kuala Lampur) ... *inquisitor* Wilkinson

16. Scutellar disc highly flattened, smooth, shiny and wholly devoid of sculpture ... 17

Scutellar disc convex, to some extent punctate, often fairly strongly, more or less dull ; pterostigma almost uniformy opaque; first tergite in apical half definitely striate, rugose, rugosopunctate or at least with a strong median rugose tumescence ... 20

17. Mesonotum highly shiny posteriorly, mainly impunctate except for a few strong punctae posteriorly. (*Bull. ent. Res.*, 19 : 133, 1928, Fiji) ... *platyedrae* Wilkinson

Mesonotum not as described above ... 18

18. Mesonotum with the punctures of the lines of natauli striate, especially in the posterior one-third and with a strong median rugose tumescence; pterostigma uniformy opaque (*Bull. ent. Res.*, 19 : 202, 1928, Malaya) ... *tirathabe* Wilkinson

Mesonotum strongly and coarsely punctate, no where striate; length of second tergite more than half the apical breadth of the first ... 19

19. First tergite striate almost throughout the apical half with finely rugose tumescence; and slightly but distinctly narrowed at the

apical third with the median tumescence only minutely rugose, finely but distinctly longitudinally striate at the apical half; propodeum with more or less weak and transverose costulae. (*Bull. ent. Res.*, **19**: 129, 1928, Pusa) *bambusae* Wilkinson

First tergite smooth, at most with some obscure punctae but strongly punctate in the apical half, striate laterally at extreme apex; costulae strong and opapue; without median tumescence; ovipositor sheath short, about as long as the hind tibiae. (*Proc. U. S. nat. Mus.*, **28**, (1413): 969, 1905, Manila, Sumatra) ... *agilis* Ashmead

20. Ovipositor sheath very short; hypopygium not membranously acute ... 21

Ovipositor sheath at least as long as hind femora; hypopygium membraneously acute; scutellar disc strongly punctate, dull; hind femora somewhat darkened above. (*Indian J. Ent.*, **7**: 9, 1945, Pusa, Muzafferpur) ... *crocidolomiae* Muzaffer Ahmad

21. Length of vein R_1 equal to that of pterostigma; hind tibial spurs equal in length but less than half the length of hind metatarsus. (*Indian J. Ent.*, **10**: 177, 1948, Lucknow) ... *indica* Bhatnagar

Length of vein R_1 greater than that of petrostigma; hind tibial spurs unequal, longer one measuring more than half the length of hind metatarsus. (*Bull. ent. Res.*, **19**: 125, 1928, Java) ... *hyposidrae* Wilkinson

22. Hind coxa red or red-yellowish-brown ... 23

Hind coxa black ... 24

23. Second tergite in ♀ nearly rectangular and about as long as the third; hind coxa dull, coarsely and minutely setigerous throughout; second suture fine and straight. (*Stylops*, London, **1**: 142, 1932, South India) ... *schoenobii* Wilkinson

Second tergite in ♀ not rectangular and also shorter than third; length of first tergite considerably greater than its apical breadth, at least one and a half to twice the breadth; mesonotum minutely punctate. (*Stylops*, London, **1**: 143, 1932, Philippines) ... *bakeri* Wilkinson

24. Tegulae testaceous, clear testaceous, red testaceous or red-yellow-testaceous; pterostigma clouded at the basal fourth; propodeum

	smooth and shiny; ovipositor sheath as long as hind tarsi. (*Stylops*, London, **1**: 141, 1932, Java) ...		*vernaliter* Wilkinson
	Tegulae dark red, reddish-brown to black, generally black ...		25
25.	Scape clear testaceous or reddish-brown ---		26
	Scape dark red, reddish-brown to black, generally black ...		33
26.	First tergite with a strong median longitudinal carina not tumescent, second tergite strongly rugose; third tergite generally almost rugose. (*Bull. ent. Res.*, **19**: 124, 1928, Kaula Lampur) ...		*hemitheae* Wilkinson
	First tergite not as described above, at most with only a faint median longitudinal carina and tumescence; third tergite always smooth		27
27.	Second tergite with a fine and definite transverse striae or aciculations in the middle at apex. (*Bull. ent. Res.*, **19**: 126, 1928, Java) ...		*caniae* Wilkinson
	Second tergite without such sulci; four anterior coxae darker than femora, usually entirely dark reddish-black to black ...		28
28.	Second tergite entirely sculptured rugose or rugulose; first tergite rugose ...		29
	Second tergite smooth or with obscure weak sculpturing, never entirely sculptured ...		30
29.	Third tergite hardly longer than second; hypopygium acute but not strongly so and not produced. (*Trans. ent. Soc., London*, p. 346, 1918, Fiji) ...		*expulsus* Turner
	Third tergite definitely longer than second; hypopygium strongly acute and strongly produced; vein R_1 longer than pterostigma. (*Bull. ent. Res.*, **19**: 127, 1928, Ceylon) ...		*heterusiae* Wilkinson
30.	Second tergite sparsely and slightly sculptured		31
	Second tergite entirely smooth ...		32
31.	Ovipositor sheath as long as the hind tarsus. (*J. N. Y. ent. Soc.*, **12**: 20, 1904, Manila) ...		*stantoni* (Ashmead)
	Ovipositor sheath longer than the hind tarsus. (*Bull. ent. Res.*, **19**: 134, 1928, Madras) ...		*fistulae* Wilkinson
32.	Second tergite slightly curved at apex; lateral sulci present; ovipositor sheath shorter than hind tibiae. (*Proc. U. S. Nat. Mus.*, **42**: 139, 1912, Bangalore) ...		*prodeniae* Vierick

	Second tergite with its apex straight and parallel to its base; lateral sulci obsolete. (*Bull. ent. Res.*, **20**: 113, 1929, Kaula Lampur) ...		*mendosae* Wilkinson
33.	Second tergite sculptured ...		34
	Second tergite smooth; pterostigma uniformly opaque ...		35
34.	Second tergite with a few extremely shallow punctae. (*Indian J. Ent.*, **4**: 164, 1942, Pusa) ...		*pusaensis* Lal
	Second tergite longitudinally rugoso-striate; vein R_1 as long as pterostigma. (*Indian J. Ent.*, **10**: 182, 1948, Pusa, Amritsar) ...		*tineaephagus* Bhatnagar
35.	Hind coxa sparsely and minutely punctate above; ovipositor sheath longer than hind tibiae. (*Indian J. Ent.*, 4. 163, 1942, Pusa) ...		*balteatae* Lal
	Hind coxa striate and coarsely and minutely punctate above. (*Bull. ent. Res.*, **22**: 77, 1931, Siam) ...		*salutifer* Wilkinson
36.	Propodeum with a strong median longitudinal carina; hind femora black ...		37
	Propodeum without median longitudinal carina; with either an areola or strong indications for an areola ...		39
37.	Hind coxa rugose. (*Ann. Mag. Nat. Hist.*, 5: 308, 1860, Ceylon) ...		*recusans* (Walker)
	Hind coxa not rugose ...		38
38.	Ovipositor sheath considerably longer than hind tarsus. (*Bull. ent. Res.*, **19**: 111, 1928, Pusa, Dehra Dun) ...		*cajani* Wilkinson
	Ovipositor sheath shorter than hind tarsus; pterostigma hyaline, bordered with reddish-brown. (*Bull. ent. Res.*, **19**: 110, 1928, Pusa)...		*detrectans* Wilkinson
39.	Thorax depressed, wider than long between tegulae; mesonotum, disc of scutellum and anterior half of propodeum on the same plane ...		40
	Thorax not as described above ...		42
40.	Vein R_1 distinctly longer than pterostigma, hind legs largely reddish-brown, scape black, pterostigma reddish-brown. (*Bull. ent. Res.*, **19**: 113, 1928, Dehra Dun, Bombay ...		*calycinae* Wilkinson
	Vein R_1 shorter than or equal to pterostigma ...		41

41. Vein R_1 shorter than pterostigma, hind legs dark reddish-brown, vein *r* twice the length of *r-m*, pterostigma hyaline. (*Indian J. Ent.*, **10**: 188, 1948, Pusa) ... *brachmiae* Bhatnagar

Vein R_1 equal to pterostigma, the later opaque, scape yellowish-red. (*Indian J. Ent.*, **10**: 190, 1948, Pusa) ... *symithae* Bhatnagar

42. Hind femora clear reddish-brown throughout... 43

Hind femora black, dark red or at least black above and below ... 46

43. Apex of first tergite in ♀ as broad as or slightly broader than its base --- 44

Apex of first tergite in ♀ narrower than its base. 45

44. Second tergite straight at its apex. (*Bull. ent. Res.*, **19**: 114, 1928, Ceylon) ... *hyblaeae* Wilkinson

Second tergite strongly curved at apex; mesonotum minutely punctate (*J. Sci. Assoc., Maharaja College, Vizianagaram*, **2**: 81, 1925, Mysore) ... *fakhrulhajiae* Mahdihassan

45. Tegulae black; scape in the greater part reddish-brown; pterostigma dark brown to black (*Bull. ent. Res.*, **22**: 76, 1931, India) ... *mycetophilus* Wilkinson

Tegulae testacepus. (*Bull. ent. Res.* **20**: 110, 1929, Shillong) ... *grandiculus* Wilkinson

46. Mesonotum closely rugose, rugose-punctate, dull and strongly setigerous, disc of scutellum largely closely but shallowly punctate, also setigerous. (*Ann. Mus. nat. Hist.*, **3**, 49, 1905, Singapore, Pusa) ... *singaporensis* Sezp.

Mesonotum shiny and generally with the punctures separate or extremely shallowly punctate; scutellar disc largely unsculptured ... 47

47. Ovipositor shaeth longer than hind tibiae ... 48

Ovipositor shaeth shorter than hind tibiae ... 53

48. Areola closed at base by straight transverse carina, the latter as strong as or stronger than lateral carinae ... 49

Areola even if present not thus closed; pterostigma hyaline in ♀, margind with brown or reddish-brown ... 50

49. Scutellar disc entirely smooth, first tergite rugose; ovipositor sheath longer than hind

tarsus; propodeum with areola well marked in apical half with a single well marked longitudinal carina in basal half. (*Bull. ent. Res.*, **19** : 118, 1928, Java) ... *araeceri* Wilkinson

Scutellar disc not entirely smooth; first tergite more or less longitudinally striate. (*Proc. U. S. nat Mus.*, **44** : 557, 1913, Bangalore) ... *phycodis* Vierick

50. Areola well marked ... 51

Areola marked only apically; propodeum with a circular excavation in middle; vein *r* longer than vein *r-m*, pterostigma hyaline, bordered with raddish-brown. (*J. Bombay nat. Hist. Soc.*, **17** : 585, 1907, Bombay) ... *leptothecus* (Cameron)

51. First tergite in ♀ rugose at the apical half, strongly tumescent in middle ... 52

First tergite in ♀ not rugose in the apical half and also not strongly tumescent in middle. (*Bull. ent. Res.*, 19: 120, 1928, Dehra Dun) *importunus* Wilkinson

52. Second tergite smooth; lateral sulci strongly curved; hind tibiae darkened in the apical two-fifths. (*Indian For. Rec.*, **4** : 19, 1913, Kheri, Dehra Dun, Bengal, C. P., Bihar, U. P., Rajputana) ... *tachardiae* Cameron

Second tergite finely aciculate; lateral sulci straight; hind tibia black in the apical two-fifths; interocellar space more than ocellocular; ovipositor sheath nearly as long as the hind tibiae; areola strongly marked at least in the apical half. (*Bull. ent. Res.*, **19**: 123, 1928, Debra Dun, Madras, C. P., Bihar, U. P., Burma, Orissa). ... *machaeralia* Wilkinson

53. Areola basally closed by a straight and transverse carina, with strong lateral carinae; scutellar disc entirely smooth; first tergite rugose. (*Spol. Zeylan.*, **6** : 43, Ceylon) ... *leptoura* Cameron

Areola basally obsolete, apically well marked at least in the later half ... 54

54. Ovipositor sheath only as long as the hind metatarsus. (*Proc. U. S. Nat. Mus.*, **54**: 567, Java) ... *javaensis* Rhower

Ovipositor sheath nearly as long as the hind tibiae, interocellar space less than the ocellocular. (*Spol. Zeylan*, **6**: 42, 1909, Ceylon) *bisulcata* Cameron

55. Second tergite sculptured ... 56

Second tergite smooth ... 75

56. Thorax wider between tegulae than high; head in lateral view conspicuously convex below antenna ... 57

Thorax not wider between tegulae than high ; head normal; second tergite devoid of sulci... 60

57. Mesonotum with coarse, strong and well developed punctae; propodeum carinate ... 59

Not as above ... 58

58. Mosonotum mostly with minute punctae. (*Africa, India*) ... *sesamiae* Cameron

Mesonotum with close and rather coarse punctae, coxa with aciculated punctae; length of vein *r* equal to the breadth of pterostigma. (*Proc. U. S. nat. Mus.*) **43**: 582, Japan, Nagpur, Burma) ... *chilocida* Vierick

59. Scutellar disc with large, shallow and scattered punctae. (*Indian J. Ent.* **10**: 135, 1948, Pusa) ... *airphicola* Bhatnagar

Scutellar disc smooth and shiny. (*Mem. Proc. Manchester Phil. Soc.*, **4**: 185, 1891, Poona). *flavipes* (Cameron)

60. Third tergite largely rugulose; mesonotum strongly and closely punctate in some parts; except some times hind femora reddish-brown; propodeum not excavate in the middle; hind coxa externally shining. (*Bull. ent. Res.*, **19** : 94, 1928, Dehra Dun, Rohatgaon) ... *ruidus* Wilkinson

Third tergite smooth, at least not rugulose .. 61

61. Hind coxae rugose, dull. (*Ent. Mag.*, **2**: 253, 1835, Coimbatore, Bihar, U. P. Madras, Ceylon, Cuttack, Hyderabad) ... *ruficrus* (Haliday)

Hind coxae smooth or only closely punctate, shining ... 62

62. Vein *r-m* longer and stouter than vein *r*; vein *SR* as a distinct stump; vein R_1 as long as pterostigma; scutellar disc with the punctae deep and well separated. (*Indian J. Ent.*, **10**: 141, Bihar) ... *jayanagarensis* Bhatnagar

Veins not as described above ... 63

63. Head almost with strong and well separated punctures. (*Proc. U. S. nat. Mus.* **18**: 647, 1896, Ceylon) ... *pratapae* Ashmead

Head sculpture not as described above ... 64

64. Hind coxa mostly reddish-brown; mesonotum strongly punctate; scutellar sulcus with eight

carinae; scape mostly reddish-brown; ocellocular space not less than the interocellar; basal carina of propodeum strong. (*Indian J. Ent.*, **10**: 143, 1948, Bihar, Agra) ... *bosei* Bhatnagar

Hind coxa black or nearly so ... 65

65. Mesonotum not coarsely and strongly punctate, at the most with shallow, coalescent punctae ... 66

Mesonotum at least partially and coarsely punctate ... 67

66. Propodeum with strong median longitudinal and transverse basal carinae; lateral sulci of the second tergite equally deep for the whole of its length. (*Spol. Zeyloy.*, **6**. 41, 1909, Ceylon) ... *paludicolae* Cameron

Propodeum with weak longitudinal carinae and no transverse basal carina; lateral sulci of the second tergite deeper anteriorly than posteriorly. (*Syst. nat.*, **1**: 568, 1758, Dehra Dun, Bihar) ... *glomeratus* (Linn.)

67. Propodeum with distinct transverse carina ... 68

Propodeum without transverse carina; vein *r-m* as long as vein *r*. (*Indian J. Ent.*, **15**: 23, 1953, U. P.) ... *epijarbi* Rao

68. Second tergite with lateral sulci ... 69

Second tergite without lateral sulci ... 74

69. Hind femora dark or black in the basal two-thirds or three-fourths; first tergite distinctly longer than broad and the sides not parallel; vein *r-m* equal to or longer than vein *r*; scape reddish-brown. (*Bull. ent. Res.*, **20**: 450, 1929, Bihar) ... *jnjubae* Wilkinson

Hind femora darkened only at the extreme tip 70

70. Tegulae dark red to black; vein *r-m* shorter than vein *r* ... 71

Tegulae pale or colour less; lateral sulci of the second tergite strong; interocellar space not more than the ocellocullar. (*Bull. ent. Res.*, **19**: 104, 1928, Dehra Dun) ... *hypsipylae* Wilkinson

71. Lateral margins of the first tergite converging or rounded at apex ... 72

Lateral margins of the first tergite not as described above ... 73

72. Second tergite unsculptured, shiny, hind tibial spurs unequal, longer spur two-thirds the metatarsus; pterostigma narrower than vein *r*. (*Bull. ent. Res.*, **19**: 83, 1928, Malaya, Sumatra) ... *erionotae* Wilkinson

Second tergite aciculately punctate; hind tibial spurs equal and less than half the length of metatarsus; pterostigma as broad as vein *r*. (*Indian J. Ent.*, **10** : 149, 1948, Bihar, Agra) ... *exelastisae* Bhatnagar

73. Pterostigma shorter than R_1; apical portion of vein *M* about equal to the pigmented portion of vein M_{1+2}; third tergite yellow. (*Proc. U. S. Nat. Mus.*, **18** : 647, 1896, Ceylon) ... *tiracholae* Ashmead

Pterostigma not shorter the vein R_1; apical portion of vein *M* about equal in length to the pigmented portion of vein M_{1+2}; third tergite black. (*Bull. ent. Res.*, **19** : 103, 1928, Dehra Dun) ... *effrenus* Wilkinson

74. Vein *r* longer than vein $r-m$; hind femora and scape reddish brown; tegulae darkened. (*Proc. Mem. Manchester Phil. Soc.*, **41** : 38, 1897, Ceylon, Java, Coimbatore, Ranchi, Bangalore) *taprobanae* Cameron

Vein *r* not longer than $r-m$, at most as long as vein $r-m$; hind femora, tegulae and scape reddish-brown. (*Bull. ent. Res.*, **20** : 109, 1929, Dehra Dun) ... *malevolus* Wilkinson

75. First tergite reddish-brown, never black; lateral sulci of the second tergite not reaching the posterior margin, deeply impressed and videly divergent. (*Proc. U. S. nat. Mus.*, **42** : 145, 1912, Mysore, Assam, Kuala Lumpur) ... *papilionis* Vierick

First tergite at least partly nigresent or black ... 76

76. Propodeum with median longitudinal carina or transverse carina or both ... 77

Propodeum without carina ... 84

77. Propodeum with transverse basal carina ... 78

Propodeum without transverse basal carina; second tergite smooth ... 83

78. Vein $r-m$ shorter than *r*; second tergite with its sulci divergent only on the lateral margins. (*Indian J. Ent.*, **10** : 155, 1948, Pusa) ... *pachkuriae* Bhatnagar

Vein $r-m$ as long as or longer than vein *r* ... 79

79. Disc of scutellum smooth ... 80

Disc of scutellum not smooth ... 81

80. Petrostigma dark brown; hind coxa darkened basally. (*Indian J. Ent.*, **10** : 161, 1948, Pusa). *parasundanus* Bhatnagar

Pterostigma hyaline-brown; hind coxa uniformly reddish-brown. (*Indian J. Ent.*, **10** : 164, 1948, Pusa) ... *arginae* Bhatnagar

81. Vein R_1 as long as the pterostigma. (*Indian J. Ent.*, **10** : 165, 1948, Pusa) ... *rangii* Bhatnagar

Vein R_1 not as above ... 82

82. Vein R_1, only slightly longer than pterostigma. (*Indian J. Ent.*, **12** : 9, 1950, Pusa) ... *platypteliae* Rao & Kurian

Vein R_1 considerably longer than pterostigma. (*Bull. ent. Res.* **21**: 482, 1930, Java) ... *sundanus* Wilkinson

83. Propodeum rugose, with the median longitudinal carina prominent. (*Indian J. Ent.*, **10** : 167, 1948, Pusa) ... *euthaliae* Bhatnagar

84. Propodeum smooth, with the median longitudinal carina weakly marked; tegulae black; pterostigma dark brown; second tergite with strong diverging sulci. (*Indian J. Ent.* **7** : 10, 1945, New Delhi, Agra) ... *euproctisiphagus* Muzaffer Ahmad

84. Hind femora shiny-red or red-yellow-testaceous, except sometimes at the tips ... 85

Hind femora black, nigrescent or dark brown... 98

85. Hind coxa red or red-yellowidh-brown ... 86

Hind coxa black or strongly darkened ... 88

86. Propodeum with numerous striae and carinulae, particularly in the apical half ... 87

Propodeum neither striate nor carinulate; first tergite smooth at apex except at sides; second tergite short with its apex straight; lateral sulci very widely divergent; scape reddish brown. (*Bull. ent. Res.*, **19**: 84, 1928, Ceylon, Bihar) ... *aristolochiae* Wilkinson

87. Vein *r-m* strongly angled with vein *r*; first tergite wholly black. (*Bull. ent. Res.*, **19** : 84, 1928, Assam) ... *badgleyi* Wilkinson

Vein *r-m* not strongly angled with vein *r*; first tergite not completely black, apically punctate, hypopygium large, strongly acute. (*Proc. U. S. nat. Mus.*, **42**: 144, 1912, Mysore, Malaya, Bihar). ... *creatonoti* Vierick

88. Tegulae darkened to black ... 89

Tegulae testaceous or reddish-brown; lateral sulci of the second tergite strong, reaching apex; apex straight ... 93

89. Propodeum broadly excavated in middle, especially at base. (*Proc. U. S. nat. Mus.*, **28**: 147, 1904-1905, Manila) --- *ashmeadi* Wilkinson

Propodeum not as described above ... 90

90. Apex of second tergite more or less acutely emarginate with a small elongate area more or less convex in the middie; lateral sulci of the tergite curved at apex ... 91

Second tergite not as described above; sulci of the tergite straight at apex ... 92

91. Scape wholly reddish-brown; vein *r* equal to the breadth of the pterostigma and rounded with *r-m*. (*Spol. Zeylan.*, 5: 17, 1907, Ceylon, Bombay) ... *acherontiae* Cameron

Scape black in apical half; vein *r* shorter than the breadth of pterostigma and angled with vein *r-m*. (*Bull ent. Res.*, **19**: 264, 1928, Dehra Dun) .... *fabiae* Wilkinson

92. Scape mostly reddish-brown; cephalic portion of vein *M* always as long as its apical portion and also equal in length to the vein $M_3 + 4$; vein *SR* not indicated. (*Proc. U. S. nat.* Mus., **54**: 566, 1919, Java) --- *bataviensis* Rohwer

Scape strongly darkened to black; veins *r* and *r-m* evenly rounded; hind femora not darkened at apex. (*Proc. U. S. nat. Mus.*, **42**: 143, 1912, Mysore) --- *eolemani* Viereck

93. Lower posterior angle of hypopygium, viewed from side, acute or truncate ... 94

Hypopygium not as above, either rounded or not clearly defined or sharply cut away to form a short lower posterior margin; second tergite with the lateral sulci not very wide and divergent; scape dark or black; antenna in ♀ as long as or longer than body; vein *r-m* shorter than vein *r*; first tergite with sides nearly parallel upto the basal three-fourths or four-fifths, then converging to apex. (*Bull. ent. Res.*, **22**: 76, 1931, Java) ... *plutellae* Wilkinson

94. Veins *r* and *r-m* not meeting at an angle ... 95

Veins *r* and *r-m* angled; hind coxa large, minutely punctate; as long as or longer than the first two tergites combined, fore coxae clear reddish-brown; mesonotum pruinose and only minutely punctate ... 97

95. Propodeum dull, usually with much fine striation and punctae, occasionally rugose; lateral sulci of the second tergite diverging with an angle less than a right angle; mesonotum with well marked punctation in apical half; first tergite indefinitely punctate apically; hypopygium distinctly acute; hind coxa, partly or wholly smooth and shiny. (*Bull. ent. Res.*, **19** : 82, 1928, Madras, Punjab, Dehradun) ... *oblique* Wilkinson

Propodeum shiny, smooth, almost with some sparse minute punctae; ovipositor sheath as long as the hind metatarsus; hypopygium large ... 96

96. Second tergite wholly impunctate; lateral sulci straight; hypopygium acute; hind coxa impunctate externally. (*Bull. ent. Res.*, **19** : 88, 1928, Kuala Lumpur) ... *lamprosemae* Wilkinson

Second tergite weakly sculptured; lateral sulci curved so that they are nearly parallel at apex; hypopygium more truncate than acute; hind coxa minutely punctate externally. (*Bull. ent. Res.*, **19** : 90, 1928, Malaya) ... *lamborni* Wilkinson

97. Scape clear reddish-brown; lateral sulci of second tergite diverging at hardly less than a right angle. (*Bull. ent. Res.*, **19** : 89, 1928, Bengal, Assam). ... *puera* Wilkinson

Scape darkened; lateral sulci not so widely divergent; ovipositor sheath long, narrow and uniformly thick. (*Proc. U. S. nat. Mus.*, **54** : 566, 1918-19, Java) ... *bellipae* Rhowea

98. Middle femora entirely light brown or yellow; hind femora reddish-brown ... 99

Middle femora nigrescent, at least basally; hind femora deep red to black ... 101

99. Hind coxa red, concolourous with femora; middle femora yellow. (*J. N. Y. ent Soc.*, **12** : 19, 1904, Manila) ... *philippinensis* Ashmead

Hind coxa black; middle femora reddish-brown 100

100.	Second tergite with its lateral sulci slightly curved. (*Bull. ent. Res.*, **19** : 91, 1928, Kuala Lampur) ...	*corbetti* Wilkinson
	Second tergite with straight lateral sulci. (*Bull. ent. Res.*, **19** : 91, 1928, Sumatra) ...	*phytometrae* Wilkinson
101.	Prpodeum smooth; pterostigma not shorter than vein R_1 ...	102
	Propodeum with numerous carinae and carinulae ...	103
102.	Pterostigma equal to R_1. (*Indian J. Ent.*, **10** : 171, 1948, New Delhi) ...	*mujtabai* Bhatnagar
	Pterostigma longer than R_1. (*J. Bombay nat. Hist. Soc.*, **17** : 102, Quetta) ...	*nigrescens* (Cameron)
103.	Second tergite with lateral sulci straight. (*Proc. ent. Soc. Washington*, **28** : 188, 1926, Kuala Lampur) ...	*artonae* Rhower
	Second tergite with the discal sulci slightly curved. (*Bull. ent. Res.*, 19 : 93, 1928, Java)	*taylori* Wilkinson

THE MORPHOLOGY OF THE FEMALE REPRODUCTIVE ORGANS OF PANTALA FLAVESCENS FABRICIUS (Libellulidae: Odonata)

By

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INTRODUCTION

Siebold (1840), Palmen (1884), Fenard (1897) and van der Weele (1906) were among the early workers who investigated the external genital organs of the female Odonata. Marshall (1914) described the anatomy of the reproductive organs in *Libellula quadrimaculata* Linn. George (1928) gave a brief account of the morphology and the development of the reproductive organs and the genital ducts in *Agrion*. The best general work on the reproductive organs of female dragonflies is perhaps that of Tillyard (1917).

MATERIAL AND METHOD

The adults of *Pantala flavescens* Fabricius were captured with a large net, mostly during the months of August and September. For histological studies, the dragonflies were pinned alive in a small dissecting dish and were dissected in 0·75% sodium chloride solution. The reproductive organs were fixed for 18—20 hours in a mixture of picro-formol-acetic Acid in the ratio 3:1:0·2. Serial sections 6—8 micra thick were stained either with Delafield's haematoxylin or Heidenhein's haematoxylin and counterstained with eosin. Whole mounts of the internal genital organs were fixed in Bouin's fluid, stained in borax carmine and mounted in thick canada Balsam after treating them through the usual procedure of washing and dehydration.

ACKNOWLEDGMENTS

The authors are thankful to Prof. M. D. L. Srivastava, Head of the Zoology Department, Allahabad University, for facilities for work, and to Mr. D. E. Kimmins of British Museum, London for identifying the specimen.

GROSS MORPHOLOGY OF THE INTERNAL GENITAL ORGANS

The internal genital organs consist of paired ovaries, paired oviducts, an unpaired short common median oviduct, a highly muscular complex organ, the bursa copulatrix, a single, inconspicuous median spermathecal sac, paired lateral accessory spermathecal sacs and a vagina. The bursa copulatrix, the spermathecal sacs and the vagina together form a single structure, the '8th Complex', which lies posteroventral to the last abdominal ganglion. Definite accessory glands are absent.

The Ovaries—The ovaries are a pair of large, elongated and pale-brownish-white organs, which extend from the base of the abdomen upto the end of the fifth abdominal segment (Plate I, fig. 1) and measure 13·82 mm in length. The ovaries remain dorsal to the crop upto the third abdominal segment but further posteriorly

they bend down and lie subdorsally to the alimentary canal. The two ovaries are united by a median ligament in the middle on the dorsal side of the crop, forming a very prominent structure. The united portion of the ovaries may extend beyond the third abdominal segment but is usually confined to the fourth segment. The median ligament, which unites the two ovaries in the anterior region, continues posteriorly, joining the ovaries at places in its course upto the ninth abdominal segment, where it is attached to the dorsal side of the body wall. A large lateral oviduct extends subdorsally throughout the whole length of the ovaries on the outer side.

Each ovary consists of a very large number of ovarioles, arranged longitudinally on the ventral side of the lateral oviduct. The ovarioles are long cylindrical structures, packed closely together, forming a compact ovary. The arrangement of the ovarioles on the lateral oviduct differentiates the ovary into dorsal and ventral surfaces. The filamentous apical end of the ovariole lies embedded in the tissue of the median ligament and is directed towards the anterior side. These small filaments of the ovarioles combine together anteriorly to form a comparatively thick structure, the filament of the ovary (Plate I, fig. 2). The filaments of the two ovaries may remain separate or they may unite together to form a single median structure, which is attached to the wall of the thorax. The ventral side of the ovary is richly supplied with tracheae and tracheoles which form a sort of reticulum over the surface. Fat bodies, though lying close to the ventral side of the ovary, do not, however, form an envelope round it and are easily separated off from the gonad. The ovaries are held in position by terminal filaments, the median ligament, tracheae and tracheoles and to some extent also by fat-bodies.

The Paired Oviduct—The lateral oviduct, which extends through the entire length of ovary, becomes lateral to the alimentary canal in the sixth abdominal segment and continues posteriorly as the oviduct. Each oviduct is a comparatively thick-walled tube, measuring 9·09 mms in length and extending from the beginning of the sixth abdominal segment upto the middle of the eighth abdominal segment (Plate I, fig. 1). Near the anterior region of the eighth abdominal segment, it turns ventralwards and inwards and comes to lie ventral to the alimentary canal. The oviducts contain eggs in a chain and if without eggs collapse soon on treatment with the fixing fluid.

The Median Common Oviduct—The two oviducts join each other about the middle of the eighth abdominal segment to form a short but distinctly visible common median oviduct (Plate I, fig. 3), immediately dorsal to which lies the eighth abdominal ganglion. The common median oviduct is a simple canal of a larger dimension and opens posteriorly into the vagina through the female gonopore.

The Vagina—It is a simple tube, which is visible clearly on the ventral side of the '8th complex' in the mid-ventral line and lies laterally compressed by two thick groups of muscle bundles (Plate I, fig. 4). The vagina communicates to the exterior through the female genital aperture.

The Bursa Copulatrix—The cavity of the vagina on the dorsal side is greatly developed and forms a highly muscular pouch-like organ, the bursa copulatrix (Plate II, fig. 6). The bursa copulatrix constitutes a major portion of the eighth complex ('8th Complex') lying in the posterior half of the eighth abdominal segment and in the living state shows rhythmic pulsations. Fat bodies and tracheae lie closely applied to this organ. Near the middle on the dorsal side of the '8th complex', there is an incomplete ring-like sclerotic plate, the collar, which divides

PLATE I

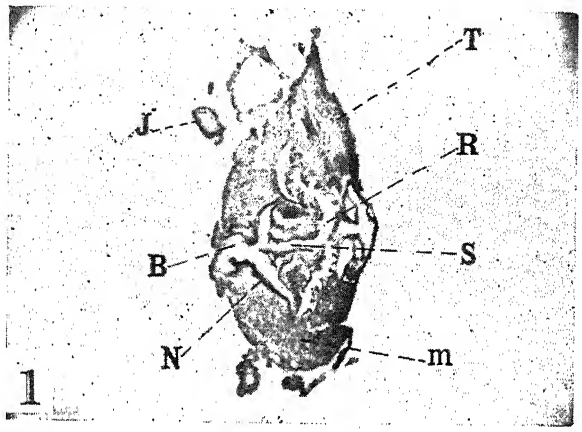


Fig. 1. Microphotograph of T. S of '8th Complex' (10×0× 6×E).

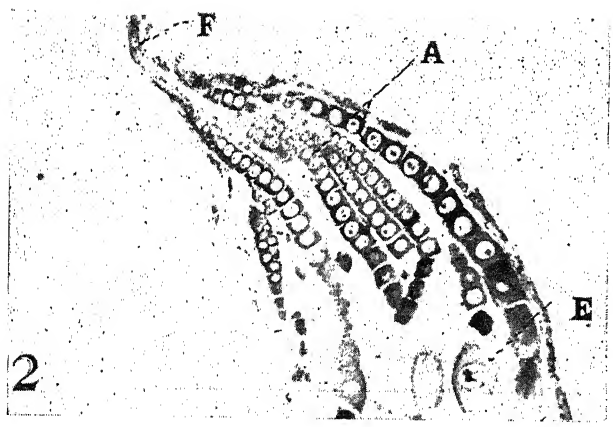


Fig. 2. Photomicrograph of the L. S. of anterior portion of ovary.

PLATE I—(*Concld.*)

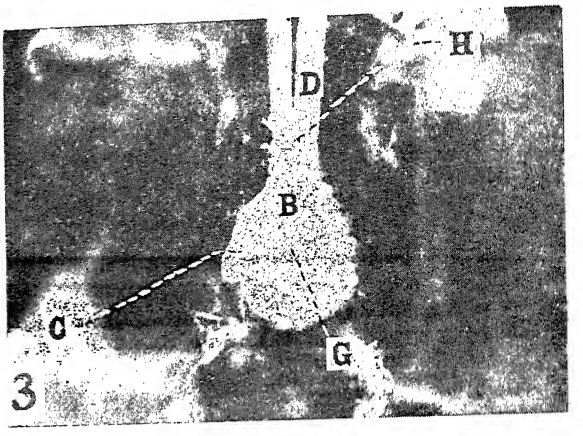


Fig. 3. Photograph of the '8th Complex'.

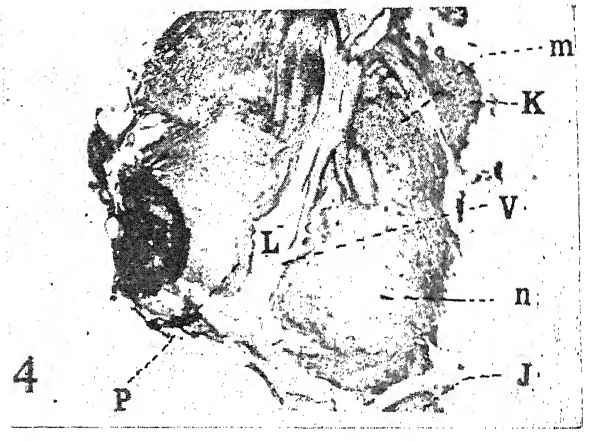


Fig. 4. Photomicrograph of L. S. of '8th Complex' (10×0×6×E).

the bursa copulatrix into an anterior and a posterior portion. This plate continues behind for some distance, lying embedded in the muscles which are firmly attached to it. The posterior limit of the collar is marked externally by two small sclerotic plates, situated symmetrically on either side of the mid dorsal line. These plates can be seen by dissecting open the '8th complex' under a binocular microscope.

The anterior portion of bursa copulatrix communicates with the vagina through a narrow and obliquely directed passage, incomplete ventrally and bearing stout spines on the inner side. This passage passes ventral to the scoop-like sclerotic piece of the collar, opening posteriorly at the level of the two anteriorly directed pouches of the posterior portion of the bursa copulatrix. The cavity of the posterior portion of bursa copulatrix is spacious dorsally and posteriorly and is continous with that of the vagina ventrally.

The Median Spermathecal Sac—The antero-dorsal region of the anterior portion of bursa copulatrix is modified into a median spermathecal sac (Plate I, fig. 3). It is an oval sac-like organ situated dorsally on the '8th complex' in the median line and acts as a reservoir for the sperms, which are transferred into the female during copulation. The median spermathecal sac communicates broadly with the anterior portion of bursa copulatrix which may also store spermatozoa.

The Lateral Accessory Spermathecal Sacs—There is a pair of sac-like glandular structures, the lateral accessory spermathecal sacs, which are directed posteriorly and situated latero-dorsal to the bursa copulatrix (Plate I, fig. 3 & Plate II, fig. 6). The two sacs open antero-terminally in the large median spermathecal sac. Each sac is a flask-like body, swollen considerably at the distal saccular end. These organs store spermatozoa and are, therefore, called the accessory spermathecal sacs.

The median spermathecal sac and the lateral accessory spermathecal sacs are not distinct, as they remain embedded in a thick mass of adipose tissue.

HISTOLOGY OF THE INTERNAL GENITAL ORGANS

The Ovaries—Each ovary is composed of an enormous number of panoistic ovarioles, in which the nurse cells are totally absent. Connective tissue and fat bodies in thin layers are present in between the ovarioles.

Structure of the Ovariole—(Plate II, fig. 1) An ovariole is a long cylinder, swollen basally and tapering distally to a small and thin anterior filament. Each ovariole is surrounded externally by a thin cellular wall, which consists of a single layer of stretched cells, with the nuclei distinctly visible at the corners of the developing ova (Plate II, fig. 2). In the region of the vitellarium towards the basal side, the wall of the ovariole forms a cellular layer or the follicular epithelium (Plate II, fig. 3) round the developing oocytes. Anteriorly the wall is drawn out into a small and thin filament. Inside the wall, developing eggs are arranged in a single row, the oldest ovum being situated at the base. The wall of the ovariole is continuous with the epithelium of the lateral oviduct. The ovariole shows clearly all the three typical divisions, the filament, the germarium and the vitellarium.

The Median Ligament—The mid-dorsal median ligament is composed of fat-bodies, muscle fibres and connective tissue.

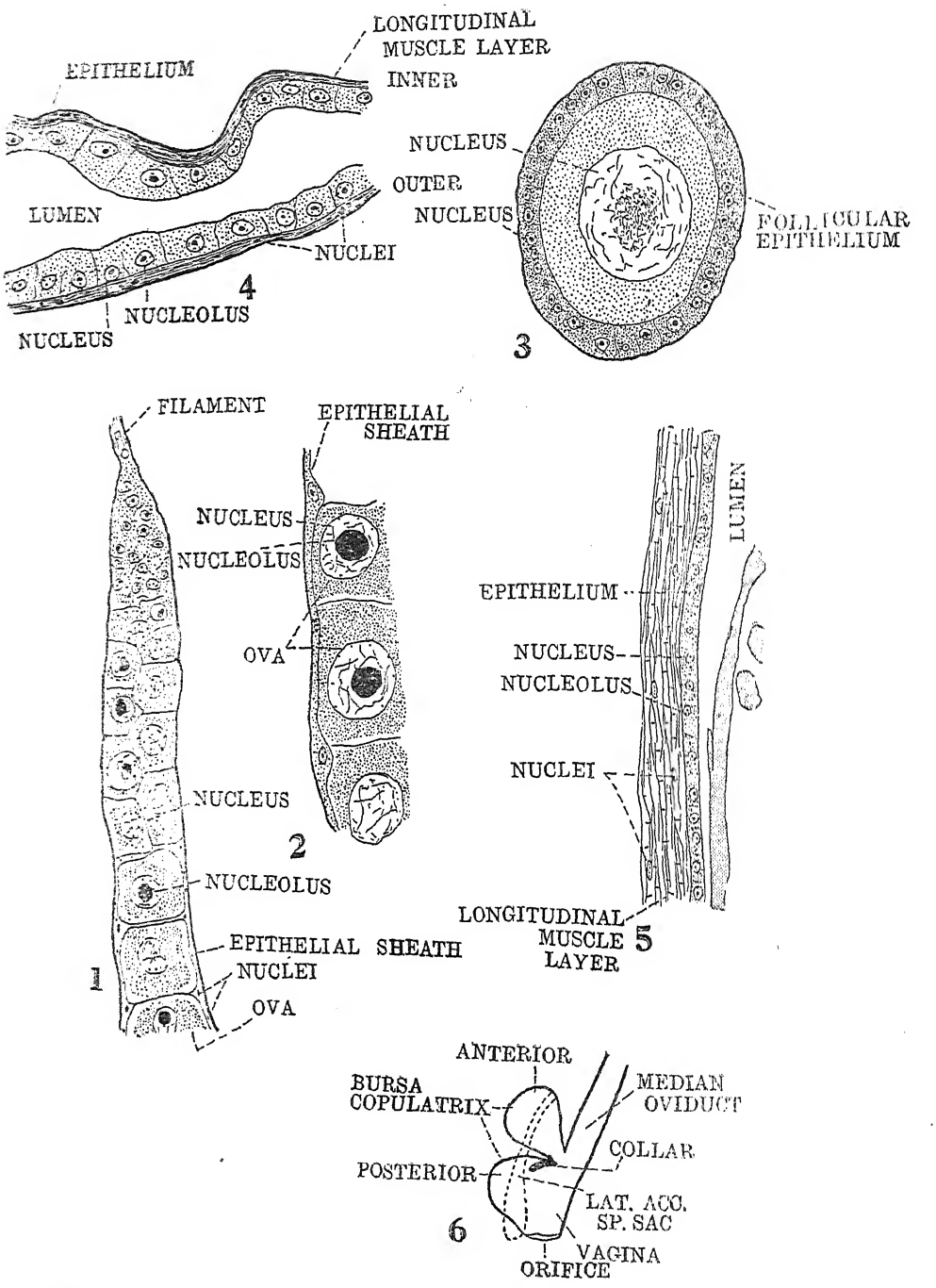


PLATE II—Fig. 1. L. S. of an ovariole (45·5×0×10×E).
Fig. 2. A portion of ovariole showing the epithelial sheath. (Under oil immersion)
Fig. 3. An ovum. (45·5×0×10×E).
Fig. 4. L. S. of Lateral oviduct. (Under oil immersion).
Fig. 5. L. S. of Paired oviduct. (Under oil immersion).
Fig. 6. Diagrammatic sketch showing the arrangement of common median oviduct, bursa copulatrix, vagina and collar etc.

The Lateral Oviduct—The wall of the lateral oviduct is made up of three layers, the inner epithelial layer, the basement membrane and the muscular coat (Plate II, fig. 4). The epithelial layer consists of flat brick-shaped cells, lining the lumen of the duct and containing distinct and somewhat oval nuclei. The epithelial cells are arranged in a single row forming a layer, which is nearly as thick as the muscle layer or may be even slightly thicker than the latter. The muscular coat is formed by a thin layer of muscle fibres, which are arranged longitudinally on the outermost side of the wall of the lateral oviduct. There is a very thin structureless basement membrane between the epithelium and the musculature and gives support to the basal ends of the epithelial cells. The epithelium of the lateral oviduct on the ventral side is well-developed and is thrown into many irregular folds. The epithelium on the dorsal side runs nearly straight.

The Paired Oviduct—The wall of the oviduct is composed of (*i*) epithelium (*ii*) basement membrane and (*iii*) musculature.

The epithelium consists of a thin layer of small, flat and brick-shaped cells, which are arranged in a single row (Plate II, fig. 5). Each of the epithelial cells contains a distinct rounded nucleus. The bases of the epithelial cells rest on a thin, hyaline and structureless basement membrane which is conspicuously visible between the stratum muscularis and the epithelium. The musculature is strongly developed on the outermost side of the duct. It consists of a thick layer of striated muscle fibres, which are arranged longitudinally and contain elongated nuclei. The longitudinal muscles form a muscular coat, which is more than three times the thickness of the epithelium. There are no circular muscles in the wall of the oviduct. There is a large lumen, through which the eggs descend down.

The lateral oviduct and the paired oviducts differ from each other in that the former is thin-walled, and the latter is thick-walled.

The Common Median Oviduct—It shows a structure exactly similar to that of the oviduct, except that the fat bodies form a layer on its outermost side.

The Vagina—The orientation of tissue in the wall of vagina is as follows (Plate I, fig. 4) :—(*i*) Chitinous lining (*ii*) epithelium and (*iii*) the musculature. The epithelium of the vagina consists of a single layer of large columnar cells with prominent nuclei. The epithelial layer is lined internally by a thick layer of chitin, which along with the underlying epithelium, is longitudinally folded. Of these, the two median longitudinal folds are very prominent. Musculature is greatly developed on the lateral sides of the vagina and consists of two groups of transversely placed striated muscle bundles which compress the cavity of the vagina laterally. The posterior end of the wall of vagina is attached to the abdominal wall by longitudinal muscles.

The Bursa Copulatrix—The bursa copulatrix displays the same arrangement of the tissue as in the vagina. The epithelial layer of bursa copulatrix is composed of large columnar cells, which are arranged in a single row. The epithelium is thrown into many irregular folds which correspond to those of the chitinous lining (Plate I, fig. 5). Muscles are seen attached to the wall of the bursa copulatrix in almost every direction. Connective tissue and fat bodies are also seen in between the muscle bundles. Fat bodies, alongwith the tracheoles, form a sac filled with air in the posterior region of bursa copulatrix.

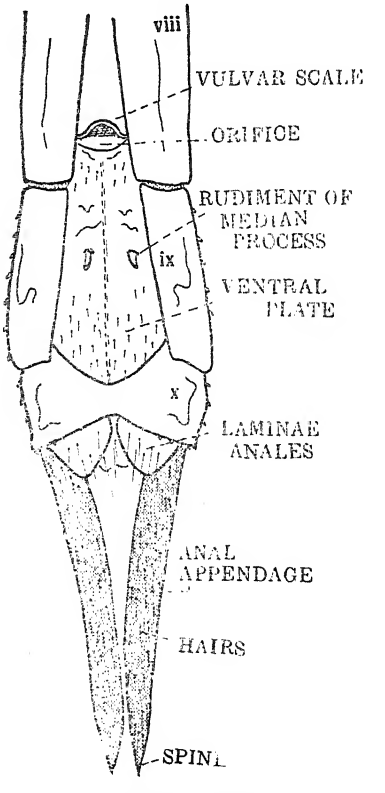
The Median Spermathecal Sac—The epithelial layer of the median spermathecal sac consists of a single row of large columnar gland cells, each containing a big

nucleus at the base. This layer is continuous with the epithelium of bursa copulatrix on the ventro-posterior side. Outer to the epithelial layer, there is a thick layer of adipose tissue, which consists mostly of fat bodies. Strands of muscle fibres are seen running in the adipose tissue. The epithelium is lined internally by a moderately thick and irregular layer of chitin.

The Lateral Accessory Spermathecal Sacs—The wall of each lateral accessory spermathecal sac is formed by a single layer of large columnar gland cells forming the epithelial lining, which is continuous with that of the median spermathecal sac on the anterior side. The epithelium of the accessory sac is lined internally by a layer of chitin and on the outer side it is surrounded by a thin layer of circularly arranged muscle fibres. The outermost layer of the wall of the lateral accessory spermathecal sac is formed by a thick layer of adipose tissue, which consists of a spongy mass of highly vacuolated cells containing large granular nuclei. The organ contains a spaceous cavity in the centre in which spermatozoa are present. The two lateral accessory spermathecal sacs open into the median spermathecal sac on the antero-dorsal side through a common opening.

EXTERNAL GENITAL ORGANS

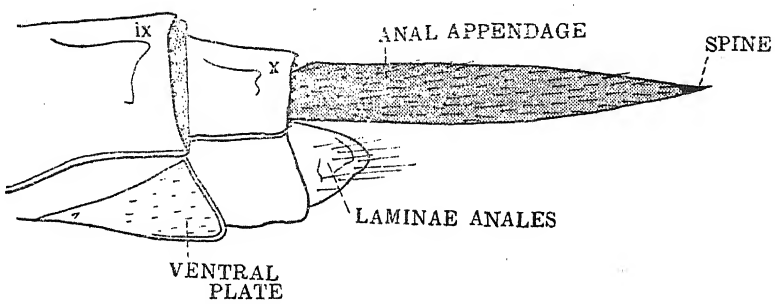
The female external genitalia of *Pantala flavescens* Fabricius consists of a pair of anal appendages, a pair of very small orange-coloured club-like appendages situated on the ninth sternum and a prominent ventral plate.



TEXT Fig. 1—Ventral view of abdominal segments VIII, IX and X (0·7 × 15)

The Anal Appendages—These are a pair of long and well-developed appendages measuring 4·133 mm. in length, emerging dorso-laterally from the last visible segment of the abdomen (fig. 1 & 2). Each appendage is an elongated rod-like tube, strongly acuminate, and of almost uniform diameter throughout. They are parallel to each other and each terminates in a very small black spine. The entire surface of the anal appendage, except the spine area, is beset with numerous stiff hairs. The posterior margin of the tenth abdominal segment is dentated more particularly in the neighbourhood of the anal appendages. Almost the whole of the appendage is coloured black, except a small area near the proximal end which is pale brown. The anal appendages of the female are as long as those of the male.

The Genital Opening or Vulva—The female genital opening is a simple and more or less oval orifice situated ventrally in between the eighth and ninth abdominal segments (Fig. 1).



TEXT Fig. 2—Lateral view of abdominal segments IX and X (1·5 × 6)

The Ovipositor—The ovipositor in *Pantala flavescens* Fabricius is very much reduced. The sternum of the eighth abdominal segment is modified into a plate-like structure, posterior margin of which is notched in the median line. This forms the vulvar scale of the animal (fig. 1). The ninth sternum is also modified into a keel-shaped, elongated ventral plate with a rounded posterior margin, which extends over the anterior region of the tenth abdominal segment (fig. 1 & 2). The posterior half of this plate bears many short bristle-like hairs. Hairs are also present in the vicinity of the genital aperture. In the middle of this keel-shaped ventral plate and on the two sides of the mid-ventral line are present two small, dark-orange coloured, club-like processes, the rudiments of the median processes of odonate ovipositor (fig. 1).

DISCUSSION

According to Marshall (1914), the ovaries in *Libellula quadrimaculata* Linn. extend from the first abdominal segment up to the middle of the sixth abdominal segment. George (1928) states that the ovaries are situated in the third and fourth abdominal segments in *Agrion*. Tillyard (1917) describes the ovaries in *Aeschna* running separately* from the base of the abdomen down to the seventh abdominal segment, dorsally on the either side of the digestive tract. In *Pantala flavescene* Fabricius, however, the ovaries begin from the first abdominal segment and end in the fifth abdominal segment. Moreover, the two ovaries remain united anteriorly and not separate as stated by Tillyard (1917).

* Shown by Tillyard in the "Biology of Dragonflies" (1917) on page 220, Fig. 97.

As described earlier, the oviducts of the two sides meet each other in the eighth abdominal segment to form a median common oviduct or the oviductus communis, also reported by Marshall (1914) in *Libellula quadrimaculata* Linn. and George (1928) in *Agrion*. According to Snodgrass (1935), the oviductus communis is an ectodermal structure being lined internally by a chitinous intima. In *Pantala flavescens* Fabricius the oviductus communis is devoid of a chitinous lining, a fact in accordance with the finding of George (1928) in *Agrion*. Therefore, the terminology of Snodgrass in respect to the oviductus communis has not been adopted in the present paper. The real nature of the oviductus communis in *P. flavescens* Fabr. can be revealed only by studying its development.

Since the vagina, the bursa copulatrix, the spermatheca and the lateral accessory spermathecal sacs are not clearly visible externally and only microtomic sections reveal their identity, these organs have been collectively called the '8th complex' for convenience in description. The presence of so many structures in the female reproductive system is probably due to the fact that the female dragonfly copulates with male only once in her life. The complicated mechanism of copulation alongwith the above mentioned complex set of organs ensures the laying of potent (fertillized) eggs by the female throughout life.

Tillyard (1917) states that the fertilization occurs in the oviducts. The present work does not confirm this, as no sperms have been observed either in the oviducts or in the median common oviduct. It is snggested that as the eggs pass down into the vagina from the median common oviduct through the '8th complex', they are fertilized by the sperms descending from the spermatheca in which they are always present. The rhythmic pulsations shown by the 'eighth complex' in the living condition of the insect seem to assist the eggs and the sperms to descend down.

The absence of the accessory glands can be explained by the fact that the secretory function has been taken up by the glandular epithelial wall of the median spermatheca and the lateral accessory spermathecal sacs.

SUMMARY

1. The ovaries are a pair of large, elongated cord-like organs lying dorsally over the alimentary canal and extending from the first abdominal segment upto the fifth abdominal segment.
2. The two ovaries are united anteriorly by a median ligament in the first three abdominal segments.
3. Each ovary consists of a very large number of panoistic ovarioles, differentiated clearly into three regions, filament, germarium and the vitellarium.
4. The ovarioles are attached on the ventral and inner sides of a large thin-walled lateral oviduct and are arranged longitudinally on it being directed anteriorly and ventrally.
5. The lateral oviduct runs on the dorso-lateral side of each ovary through its entire length. Posteriorly the lateral oviduct continues beyond the region of the ovary and forms the paired oviduct.
6. The wall of the lateral oviduct consists of an epithelial layer surrounded externally by a muscle layer which is nearly as thick as the epithelium.

7. The muscle layer in the wall of the paired oviducts is more than three times the thickness of the epithelium.

8. The paired oviducts are simple tubes extending from the beginning of the sixth abdominal segment upto nearly the middle of the eighth abdominal segment.

9. The two oviducts join each other in the eighth abdominal segment to form a short median common oviduct, concealed beneath the large eighth abdominal ganglion.

10. The lumen of the median common oviduct is not lined by chitinous intima.

11. The median common oviduct leads into a structure termed '8th Complex'. It is a highly muscular organ showing rhythmic pulsations in the living condition of the insect.

12. The '8th Complex' consists of a vagina, bursa compulatrix, median spermatheca and a pair of lateral accessory spermathecal sacs.

13. The wall of the vagina on the ventral side is thrown into longitudinal folds.

14. There is an incomplete ring-like chitinous collar embedded in the wall of the mid-dorsal side of the bursa copulatrix, dividing it into two parts, an anterior spermathecal portion and a posterior copulating pouch.

15. The vagina and the bursa copulatrix are lined internally by a thick layer of chitin.

16. The wall of the spermatheca and the lateral accessory spermathecal sacs is glandular.

17. Fertilization takes place in the '8th Complex'.

18. The female genital opening is a large transversely elongated orifice, situated ventrally inbetween the eighth and the ninth abdominal segments.

19. The female external genitalia consists of a pair of anal appendages, a pair of very small orange-coloured club-like appendages situated on the ninth sternum, a vulvar scale and a ventral plate.

20. The anal appendages are as long as the supra-anal appendages in the male.

21. Club-like appendages represent the vestigial median processes of the typical Odonatan ovipositor.

22. The ventral plate is well-developed and keel-shaped.

23. The accessory glands are totally absent.

KEY TO LETTERING

A—Ovarioles; B—Median spermatheca; C, J—Lateral accessory spermathecal sacs; D—Oviduct; E—Oocyte; F—Filament; G—Collar; H—Common median oviduct; K—Adipose tissue; L—Lumen; M—'8th Complex'; N—Chitinous intima; O—Ovary; P—Columnar epithelial cells; R—Bursa copulatrix; S—Lumen in the anterior portion of the bursa copulatrix; T—Transverse group of muscles; V—Vagina; m, n—Muscles.

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STUDIES ON THE EFFECT OF PYRUVIC ACID ON RESPIRATION AND SUGAR CONTENTS OF GREEN LEAVES

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Pyruvic acid has been found to be formed during the alcoholic fermentation of sugar. The work in this connection has been summarised by Kostychev[1].

James and Norval[2] worked on the respiratory decomposition of pyruvic acid by barley. They found that killed barley tissues were able to break down pyruvic acid into acetaldehyde; germinating embryos and young detached leaves increased their rate of carbon dioxide emission when supplied with dilute solutions of pyruvic acid. They concluded that pyruvic acid was likely to be a normal intermediary in the respiration of barley. James and James[3] provided additional evidence for the view that pyruvic acid was an intermediate in barley respiration; the conclusion was arrived at by poisoning and inihibition of the enzyme carboxylase, James, James and Bunting[4] from their observations on the respiration of barley worked out a scheme on the method of pyruvic acid formation.

In view of these observations and in view of the fact that pyruvic acid or pyruvate is in an integral part of the Krebs cycle, it would seem worth while to examine the effect of pyruvic acid on the respiration of green leaves.

MATERIALS AND METHODS

The leaves chosen in this connection were those of *Eugenia jambolana* (= *Syzygium cumini*). Dilute solutions of pyruvic acid in distilled water were introduced into the leaves. Two sets of leaves were taken and their normal respiratory rates were recorded for 24 hours; at this point one set was injected with pyruvic acid solution and the other with distilled water to serve as control. There after the respiratory rates were measured for another 24 hours. Estimations of disaccharide and monosaccharide contents were made of fresh leaves and at the time of injection and also at the close of carbon dioxide measurements. Similar estimations were also made with fresh leaves of *Allium tuberosum* and those injected with pyruvic acid solutions and distilled water and kept for 27 hours. Details of the methods used in respiratory measurements and sugar estimations have been given elsewhere[5,6].

RESULTS AND DISCUSSION

It has been found that 0·5, 1·0 and 2·0 percent solutions accelarated the respiratory rate but a concentration beyond 2 percent depressed the carbon dioxide value below that of the water injected leaves which served as control. Before proceeding with the analysis of data with regard to pyruvic acid any further, it would be desirable to know the amounts of pyruvic acid that entered the leaves when injected with the various solutions. The amounts have been shown in Table I.

TABLE I

The amounts of pyruvic acid entering the leaves by injection

Percentage of pyruvic acid injected	Mgm. of pyruvic acid entering per 10 gm. of leaves
0·5	20·2
1·0	39·0
2·0	75·1
3·0	104·1

As is natural, the amounts of pyruvic acid entering the leaves are in direct relationship with the concentration of pyruvic acid used for injection. This has been graphically illustrated in Fig. 1 in which have also been plotted the relative fluctuations of carbon dioxide production induced by pyruvic acid. The fluctuations in

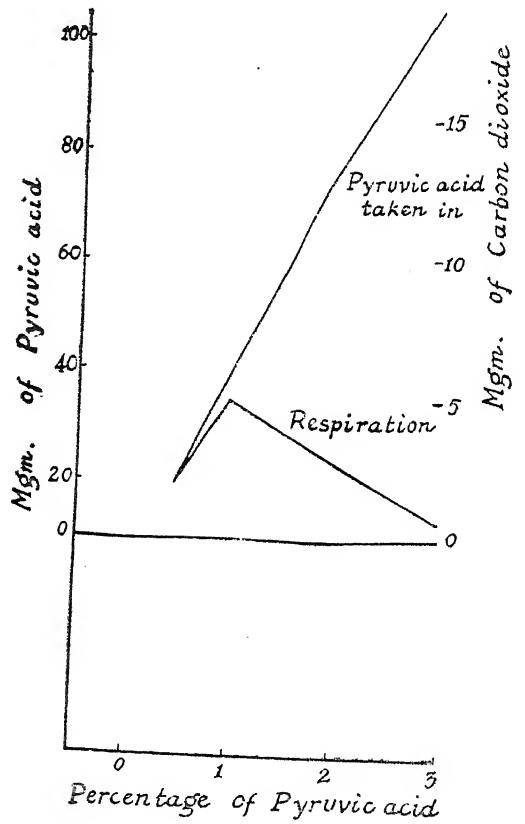

Fig. 1. The effect of pyruvic acid on respiration.

each case represent the difference between the last carbondioxide value before injection and the first one after such treatment.

For a vivid comparison of the respiratory rates as influenced by pyruvic acid, it would be better if all the respiratory drifts obtained after injections with different pyruvic acid solutions were shown in the same graph as has been done in Fig. 2. It has been obtained by the superposition of different graphs representing the effect of pyruvic acid on respiration. It will be seen that the higher is the dose of pyruvic acid the higher is the accelaration and also the level of respiration except with three percent pyruvic acid solution. The concentration of pyruvic acid in these experiments has been increased from 0·5 to 3 percent. With a 3 percent dose of pyruvic the respiratory level falls to below of the water-injected leaves.

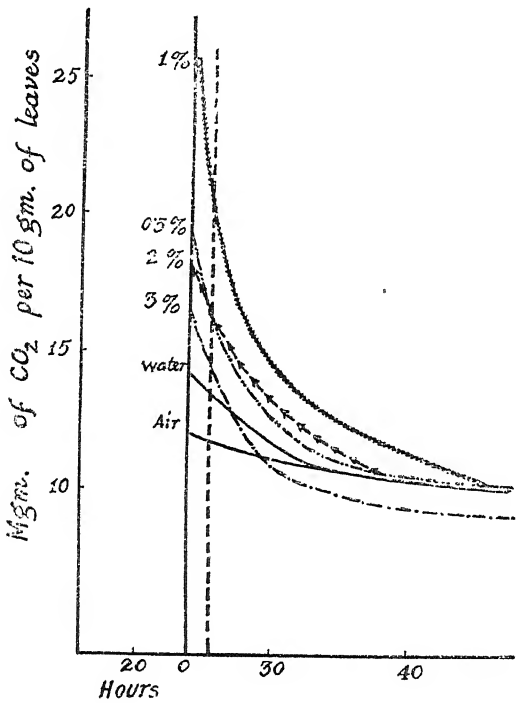

Fig. 2. Respiratory drifts with different percentages of pyruvic acid.

In Fig. 2 has also been shown the effect of pyruvic acid at the zero hour of injection *i.e.* at the time when the stimulus was applied. This has been done by extrapolating the different curves backwards to the zero-line of injection. The values thus derived by extrapolating the curves have been compared with those

actually obtained in Table II. It would be seen that both in the cases of experimental and derived values 1 per cent pyruvic acid brings about the highest stimulation of carbon dioxide production.

TABEE II

The accelaration of respiration by pyruvic acid, experimental and derived values (per 10 gm. of leaves)

Respiration as stimulated by water		Respiration as stimulated by pyruvic acid		
Experimental carbon dioxide values in mgm.	Derived carbondioxide values in mgm.	Percentage of pyruvic acid injected.	Experimental carbon dioxide values in mgm.	Derived carbondioxide values in mgm.
0·97	2·0	0·5	2·4	5·2
,,	,,	1·0	5·4	11·6
,,	,,	2·0	2·6	4·4
,,	,,	3·0	0·4	2·8

The next consideration would be the percentage of accelaration by different doses of pyruvic acid The percentage have been tabulated in Table III; these percentages are the values calculated from increase in carbon dioxide production actually obtained as well as those from data derived by extrapolation.

TABLE III

Percentage of increase in respiratory rate by pyruvic acid (per 10 gm. of leaves)

Percentage of pyruvic acid injected	Percentage from increase obtained experimentally	Percentage from increase obtained from derived values
0·5	19·04	41·25
1·0	45·0	84·17
2·0	22·6	32·1
3·0	3·57	8·03

From the records of respiratory drifts with pyruvic acid it will be apparent that the effect of pyruvic acid decreases with time ; the production of carbon dioxide is highest just after injection with pyruvic acid; after this there is a gradual fall, the carbon dioxide values returning to the air-line after 24 hours after injection. This has been made clear in Fig 3 ; the carbon dioxide output is the greatest at

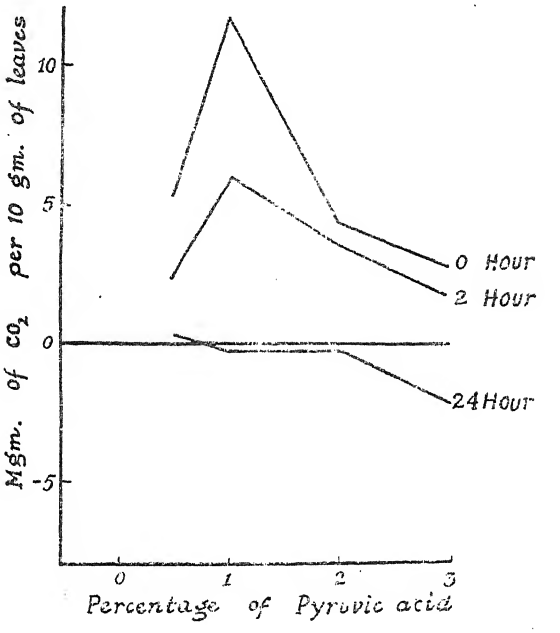

Fig. 3. The effect of pyruvic acid on the respiratory rate as related to time.

zero hour after injection, after 2 hours there is a slight decrease in accelaration and after 24 hours there is hardly and effect remaining visible. This statement of course does not apply to 3 percent pyruvic acid in which the depression of the respiratory rate is more marked after 24 hours and there is no question of a return to the normal.

After injection with different doses of pyruvic acid the carbon dioxide estimations were continued for a total period of 22 hours in each case. The total amount of carbon dioxide produced after injection is thus known for each dose of pyruvic acid. In Fig. 4 have been plotted the total values of carbon dioxide. It is clear that the total carbon dioxide production increase with the increase in the concentration of pyruvic acid; beyond 2 percent concentration, however, the production of carbon dioxide suffers a fall below the normal air-line. Thus even when a long interval of time is taken into account, the respiratory rate is accelarated by pyruvic acid from 0·5 percent to 2 percent concentration.

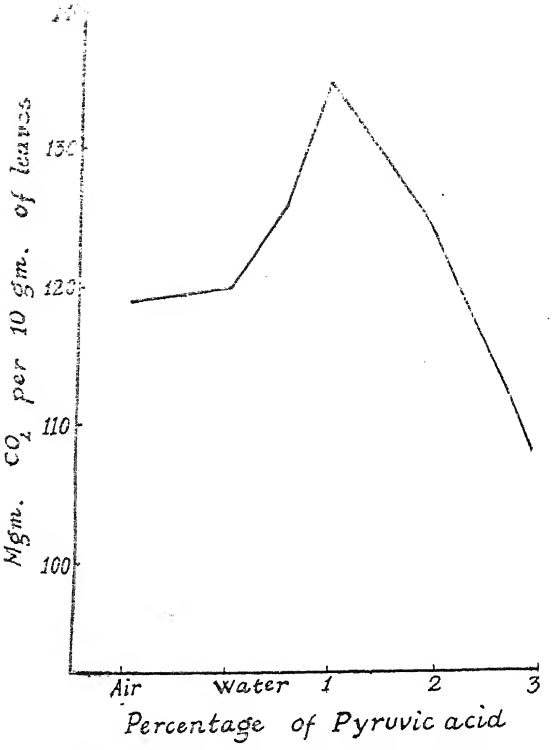

Fig. 4. The effect of pyruvic acid on total carbon dioxide production.

The effects of pyruvic acid on the sugar contents of leaves may now be examined.

TABLE IV

Comparative statement of monosaccharides utilised by water and pyruvic acid injected leaves of *Eugenia* after injection (per 10 gm. of leaves)

Mgm. of monosaccharides utilised by leaves injected with water	Mgm. of monosaccharides utilised by leaves injected with pyruvic acid	Percentage of pyruvic acid injected
28·4	11·9	0·5
29·9	13·6	1·0
30·2	14·1	2·0
30·0	13·8	3·0

It will be seen from the data recorded in Table IV that in every case the amounts of monosaccharides utilised by leaves injected with pyruvic acid stands at much lower value than that of the corresponding water-injected leaves, so much so that the values of the former are less than half of that of the latter. This amounts to saying that more monosaccharides are left over in the leaves injected with pyruvic acid than those injected with water after the same interval of time.

Similarly it would be pertinent to enquire into the extent of utilisation of disaccharides by leaves injected with pyruvic acid. This has been done in Table V.

TABLE V

Comparative statement of disaccharides utilised by water and pyruvic acid injected leaves of *Eugenia* after injection (per 10 gm. of leaves)

Mgm. of disaccharides utilised by leaves injected with water	Mgm. of disaccharides utilised by leaves injected with pyruvic acid	Percentage of pyruvic acid injected
16·6	10·1	0·5
13·8	8·0	1·0
15·3	10·8	2·0
15·8	11·6	3·0

From a study of the Table V, it would appear at once that what has been said while dealing with the monosaccharides holds true in the case of disaccharides as well. In other words both monosaccharides as well as disaccharides are appararently used to a less extent by the leaves of *Eugenia* injected with pyruvic acid ; that is when treated with pyruvic acid, both monosaccharides and disaccharides are left over in greater amounts in the treated leaves than in those injected with water. It should now be seen whether the same condition of things, so far as sugars are concerned, is obtained in the case of *Allium* as well.

TABLE VI

Comprative statement of monosaccharides utilised by water and pyruvic acid injected leaves of *Allium* after injection (per 10 gm. of leaves)

Mgm. of monosaccharides utilised by leaves injected with water	Mgm. of monosaccharides utilised by leaves injected with pyruvic acid	Percentage of pyruvic acid injected
80·1	12·1	0·5
80·1	14·4	1·0

In fact the difference between the amounts of monosaccharides utilised by leaves injected with pyruvic acid and by leaves injected with water is more marked in the case of *Allium* than in the case of *Eugenia* leaves similarly conditioned; the balance is predominantly in favour of leaves subjected to pyruvic acid injection. In order to complete the comparative estimate the disaccharide contents have also been similarly tabulated (Table VII).

TABLE VII

Comparative statement of disaccharides utilized by water and pyruvic acid injected leaves of *Allium* after injection (per 10 gm. of leaves)

Mgm. of disaccharides utilised by leaves injected with water	Mgm. of disaccharides utilised by leaves injected with pyruvic acid	Percentage of pyruvic acid injected
27·0	37·7	0·5
25·0	41·9	1·0

In contrast with the condition of monosaccharides in the case of *Allium*, larger amounts of disaccharides have been used up in leaves injected with pyruvic acid than those in water-injected leaves; that is more disaccharides are lost by the former than the latter.

So the position with regard to sugars can be defined in this way: more monosaccharides and disaccharides are left over in *Eugenia* leaves injected with pyruvic acid, more monosaccharides only are left over in *Allium* leaves injected with pyruvic acid.

The difference in the condition of sugars in the leaves of *Eugenia* and *Allium* is rather significant. It should however be borne in mind, while dwelling over the significance of this difference, that the leaves of *Eugenia* are starchy in habit, and the amount of sugar estimated with these represents only the available amount of sugar present and not the absolute value. This is so in as much as the sugar values as estimated are exclusive of the potential sources of sugars present in the form of storage carbohydrates. And these sources are largely drawn upon with the disappearence of sugar in metabolic processes, and consequently their disappearence is attended by simultaneous hydrolysis of storage carbohydrates. For the latter, the disaccharides and monosaccharides must be conceived to be occuring within the leaves in a state of dynamic equilibrium. And therefore in order to arrive at a value expressive of the actual loss of sugars, the loss sustained by the storage carbohydrates must also be taken into account. But because of their non-starchy nature, *Allium* leaves would behave differently with regard to their carbohydrate content. In these leaves potential sources of sugars are absent and on account of this absence, any fall in their sugar values would be indicative of the actual loss. And in these leaves the equilibrium would seem to exist between the monosaccharides and disaccharides only, and as the utilisation of the former brings about a lowering of their value, a corresponding conversion of the latter should be expected to take place. If this explanation holds good, the comparatively greater loss of disaccharides in the *Allium* leaves injected with pyruvic acid is as should be expected. And by may be of the same reasoning, because of the presence of storage carbohydrates in *Eugenia* leaves, the expected loss should be indicated by the depletion of the starch content and the higher value of starch disappearance, the less would be the apparent utilisation of sugars. This would explain the difference in the behaviour of *Eugenia* and *Allium* leaves with regard to their sugar values injected with pyruvic acid.

An examination of the Tables (IV, V, VI and VII) dealing with sugar values would indicate that in spite of the fact that the amounts of disaccharides register an appreciable decrease in the *Allium* leaves injected with pyruvic acid, the utilisation of monosaccharides has been rather slight; that is the monosaccharides seem to have been maintained at almost the same concentration as before the injections, In the *Eugenia* leaves on the other hand, under similar conditions, the consumption of both monosaccharides and disaccharides has been recorded to be small in amounts; or, expressed in another form, it may be said that both these forms of sugar have been maintained at nearly the same values as were recorded before pyruvic acid was introduced into the leaves. As has been suggested before, it may be assumed that the loss of carbohydrates in *Eugenia* leaves is tentamount to the disappearance of storage forms, the polysaccharides. It must be conceded that the different forms of carbohydrates within leaves are in a state of physiological balance, in which change in the value of any consituent member of the equilibriated system would necessarily disturb the concentration of the remaining ones. It is justifiable to hold that the different carbohydrates, within the leaves, were in a state of balance before or at the time the pyruvic acid injections were given. And if any quantity of sugar has been recorded to have been lost after the injection, it is reasonable to expect that the loss sustained should be equally distributed among all the forms of carbohydrates constituting the chain of balance. But, as has been shown before, the loss seems to have been suffered by the starch content of the leaves of *Eugenia*, the values of monosaccharides and disaccharides being maintained at almost the same level as before injections. In the non-starchy leaves of *Allium* the loss is registered by the disaccharides, while the monosaccharides are kept up at very nearly the pre-injection values. The conclusion that appears inevitable is that pyruvic acid has brought an alteration in the equilibrium obtaining between starch-disaccharides-monosaccharides in case of *Eugenia* leaves and between disaccharides and monosaccharides in the case of *Allium* leaves, the balance being affected in such a way as to favour the production of the simpler forms of the members of the equilibria-chain by hydrolysis of the higher ones. That the possibility of the balance being thus affected does really exist has been recorded. Thus Armstrong and Armstrong[7] have shown that leaves of cherry-laurel contain more sugar after treatment with chloroform. Hanes and Barker[8] have found that the equilibrium between starch and sugar in potato is disturbed in favour of more hydrolysis of starch to sugar by the action of very dilute hydrogen cyanide.

It has been suggested that pyruvic acid injection disturbs the starch—sugar equilibrium in favour of increasing hydrolysis of starch. The question therefore arises whether the concentration or the amount of pyruvic acid, that actually enters the leaves by way of injection, can in any way be correlated with the excess of sugar left over.

TABLE VIII

The excess of sugar and the amount of pyruvic acid entering the leaves (per 10 gm. of leaves)

Percentage of pyruvic acid injected	Mgm. of pyruvic acid entering the leaves	Excess of sugar as hexose in mgm.
0·5	20·2	23·5
1·0	39·0	22·4
2·0	75·1	21·0
3·0	104·1	20·6

It will be concluded from the study of the Table VIII that hardly any correlation exists between either the concentration or the amounts of pyruvic acid introduced into the leaves and the amounts of sugar left over in excess. The absence of any correlation would mean that the enhanced rate of the hydrolysis of storage carbohydrates may possibly be independent of, and not in any way proportional to either the concentration or to the amounts of pyruvic entering the leaves. The process of hydrolysis in that case would probably be favourably affected to the maximum possible degree under conditions obtaining within the leaf cells by only a very minute does of pyruvic acid.

SUMMARY

Experiments were performed with a view to find out the effects of pyruvic acid on the respiratory rate and sugar contents of the leaves *Eugenia jambolana* (=*Syzygium cumini*). The effect of pyruvic acid on the sugar contents of the leaves *Allium tuberosum* was also investigated.

It was found that pyruvic acid increased the respiratory rate with increasing effect from a concentration of 0·5 to 2·0 per cent, the most favourable effect was obtained with 1·0 per cent solution.

As compared to the values obtained with the control sets of leaves pyruvic acid increased the amounts of both disaccharides and monosaccharides in *Eugenia* leaves injected with it ; the increase was recorded with monosaccharides only in the case of the leaves of *Allium*. It has been suggested that pyruvic acid brings about a disturbance in starch-sugar equilibrium in *Eugenia* leaves and disaccharide-monosaccharide equilibrium in *Allium* leaves in favour of an increased hydrolysis of starch in the former and of disaccharides in the latter.

The work was carried out in Physiological Laboratories of the Botany Department, University of Allahabad, and the author sincerely thanks Prof. S. Ranjan for the facilities he provided and also for his help and guidance.

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INVESTIGATIONS ON THE PHYSIOLOGY OF JUTE

PART III—VARIATIONS IN THE PRODUCTION OF BARK AND WOOD IN CERTAIN VARIETIES OF *CORCHORUS CAPSULARIS* AND *C. OLITORIUS*

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INTRODUCTION

This is a further continuation of the investigation on the variations of different growth components in a number of important varieties of jute other than D-154 (*capsularis*) and Chinsura green (*olitorius*) the standard varieties which have been reported previously (Kar and Desarkar 1954). As the two species of jute *Corchorus capsularis* and *C. olitorius* are not yet found to be intercrossable, it was thought essential to investigate the nature of growth and the consequent production of different components which determine the yield of fibre. Such investigations may provide data for a comparative analysis of the different varieties within a species as well as may indicate inter-specific variations. The following varieties have been investigated :—*capsularis varieties*—JRC-212 ; JRC-13 ; JRC 32; *olitorius varieties*—JRO-620 ; JRO-632 ; JRO-753 ; and R26. The results have been described under (*a*) production of bark and wood at important phases of growth (*b*) consequent production of total dry matter and (*c*) the percentage relation with each other in reference to fibre production.

METHOD

The varieties were sown in replicated plots of 21′ × 14′ size in four replications. The sowing was done in lines by hand-dibbling at a spacing of 2″ from plant to plant and 1 ft from row to row. For purpose of sampling, about 200 plants were numbered at random after one month growth and at the time of sampling lots were prawn to take the plant material for analysis from amongst the numbered plants (Kar and De Sarkar 1954).

For laboratory estimation of different growth components like bark, wood and fibre, three plants were taken on average at each sampling. In order to have detailed results each plant stem, after removal of the leaves, was divided into 6″ segments begining from the bottom towards the apex. The green weight of the segments was taken and then the bark was carefully stripped off with the help of a scalpel, thus separating the bark from the wood portion. Both of them were numbered and dried in an oven kept at 60° to 80°C. The moisture content and the corresponding dry weight of the bark and wood were determined which thus provided the results on the production of the components at different stages of growth, as well as the distribution of the same along the length of the growing stem.

EXPERIMENTAL RESULTS

Production of bark and wood at important phases of growth in capsularis varieties :

The results have been obtained after each fortnight; but to bring out the significant differences in the growth of the above components and the consequent total dry matter formed, important stages like vegetative stage, bud-stage, flower stage and pod stage have been considered here. So the manifestation of growth in terms of height and basal diameter has been further worked out by detailed quantitative estimation of production of green and of dry matter in the stem at different phases of plant growth as well as in different regions or height of the plant. The addition of dry matter is the best indication of the growth of the plant and in jute we are concerned with the variation of dry matter in the plant stem and its distribution in the bark and wood portions. Such result obtained in the *capsularis* varieties have been tabulated in table I.

TABLE I

Showing the bark and wood formed for equal lengths of stem at different ages in *capsularis* varieties. Dry weight in gms.

Age in days and different stages	51 days (vegetative stage)		72 days (Bud stage)		93 days (Flowering stage)		121 days (pod stage)	
Length of stem	0-30″		0-48″		0-72″		0-78″	
Components	Bark	Wood	Bark	Wood	Bark	Wood	Bark	Wood
Varieties-								
JRC-212	1·215	1·118	2·704	2·797	5·742	5·361	11·195	12·987
JRC-13	0·948	1·124	2·776	2·873	6·075	6·468	12·290	15·011
JRC-321	1·723	1·585	2·964	3·082	5·737	5·321	11·254	14.565

From the values of bark and wood weights tabulated at 51 days growth, JRC-321 showed a higher weight which was continued upto bud stage. But in the flowering stage a rapid increase was noticed in JRC-13 which recorded the maximum value in the late pod stage of 12·290 gms. as compared to 11·254 gms. in JRC-321 which was more or less similar to that of JRC-212. The wood weight also increased in the same way, but recorded a minimum value in case of JRC-212 in the pod stage. The range of difference in bark weight in the varieties was less than that of the corresponding wood weight. This difference might be due to the rate of impregnation of the xylem vessels as compared to those of fibre cells contained in the bark region, where a certain percentage of bark cells were specifiized into fibre cells. The formation of the bark and wood components was indicative of the nature of growth in the varieties, during the active vegetative growth period and at the time of initiation of the flowering period when marked changes were noticed. Bark and wood were simultaneously formed as a result of cambium activity which increased appreciable with the onset of flowering period, and the rate of increase, as recorded by bark and wood formation, differed in the different varieties.

Percentage of bark formation on total dry weight

The contribution of percentage of bark weight to the total dry weight is very important, because on this depends the fibre output of a variety as fibre is contained in the bark. The values of bark and wood have, therefore, been considered from the above point of view. The percentage values of bark on total dry weight have been tabulated in table II.

TABLE II

Showing variations in percentage bark formation on total dry weight at different stages of growth in *capsularis* varieties

Age in days and different stages	51 days (vegetative stage)		72 days (bud stage)		93 days (flowering stage)		121 days (pod stage)	
	Dry wt.	% Bark	Dry wt.	% Bark	Dry wt.	% Bark	Dry wt.	%Bark
Varieties								
JRC-212	2·333	52·08	5·510	49·07	11·103	51·72	24·185	61·29
JRC-13	2·072	45·74	5·649	49·14	12·543	48·43	27·265	45·08
JRC-321	3·308	52·09	6·046	49·02	12·058	47·58	25·822	43·78

The percentage values indicated that in the early vegetative stage about 50% of the total dry weight constituted the bark weight, except in JRC-13 where the value recorded was low. In later stages during the flowering period the percentage values decreased showing thereby an increase in the wood weight. But JRC-212 always showed a higher percentage of bark which indicated the higher fibre yielding capacity of the variety as compared to the other two varieties. The fibre weight and bark weight are positively correlated, therefore an increase in bark yield meant increase fibre output. It was noted that JRC-13 which recorded maximum bark and wood weight on the otherhand showed a lower percentage of bark, which reflected upon its fibre yielding capacity. Actually JRC-212 was found to be a high yielding variety and considered as selected improved type.

Percentage distribution of bark :

The significance of bark formation was further studied from the point of view of its distribution along the stem, which has been done by calculating the percentage of bark located in the three broad regions of the stem as top, middle and bottom, in terms of total bark weight of the whole length of the stem. The values of persentage distribution of bark have been tabulated in table III, for the different varieties at different growth phases.

TABLE III

Showing percentage distribution of bark in Bottom, Middle and Top regions of stem in terms of total bark weight of the whole length of the stem in *capsularis* varieties

Age in days and different ages	51 days Vegetative			72 days Bud stage			93 days Flowering stage			121 days Pod stage		
Stem	B	M	T	B	M	T	B	M	T	B	M	T
JRC-212	57·20	31·44	11·36	52·8	34·32	12·83	52·09	33·32	14·59	49·76	33·37	16·87
JRC-13	60·86	29·32	9·81	57·64	29·47	12·90	49·37	33·48	17·15	50·17	32·64	17·19
JRC-321	51·01	38·19	10·80	53·54	29·56	16·90	46·38	34·76	18·86	50·62	33·36	16·02

B = Bottom; M = Middle; T = Top.

A greater percentage of fibre was concentrated in the bottom and middle regions, showing a greater rate of cambial activity in these regions. In other words the intensity of fibre growth increased from apical regions towards the basal regions of the stem where many layers of fibre cells were formed. In all the varieties, after individual varietal differences noted during the vegetative and flowering stages, the values of percentage distribution were found to be similar in all the varieties at the pod-stage when the plants were harvested. About 50% of the bark was formed in the bottom regions, 33% in the middle and rest about 17% in the top regions.

The estimations of bark and wood at different regions of the stem and at the different growth phases also showed a very coordinated growth of the two components. In the vigourous growing region of the apical portion of the stem the ratio of bark formation to wood formation in terms of dry weight was found to be 1:1. The value of this ratio gradually decreased from the apical region towards the basal region showing an increase in wood weight due to the greater lignification and impregnation in the xylem cell walls.

Production of bark and wood at important phases of growth in olitorius varieties :

The olitorius varieties were also treated similarly as those of *capsularis* varieties in estimating the green weight, dry weight, bark and wood weight at different phases of growth for equal lengths of stem. The results obtained have been tabulated in table IV.

TABLE IV

Showing the bark and wood formed for equal lengths of stem at different ages in *olitorius* varieties. Dry weight in gms.

Age in days and different stages	51 days (Vegetative stage)		72 days (Bud stage)		93 days (Flowering stage)		121 days (Pod-stage)	
Length of stem	0-30″		0-48″		0-72″		0-78″	
Components	Bark	Wood	Bark	Wood	Bark	Wood	Bark	Wood
Varieties								
JRO-632	1·507	1·176	4·220	4·504	8·035	7·734	16·903	19·957
JRO-620	0·954	0·975	4·222	4·281	7·00	6·292	15·418	19·532
JRO-753	1·823	1·310	4·209	4·358	7·981	6·653	13·328	14·436
R-26	1·620	1·322	4·636	4·534	5·317	5·942	11·992	17·660

In *olitorius* varieties also the nature of growth of bark and wood is similar to that of *capsularis* varieties as described before. The values showed that in early vegetative stages the varietal differences were very marked. In the early vegetative stage of 51 days growth, the weight of total bark recorded in JRO-620 was the minimum, which increased appreciably in the later stages reaching a value of 15·418 gms. in the pod stage of 121 days for a length of 78" of the stem which value was only lesser than that of JRO-632 (16·903 gms) but higher than the other two varieties. In R-26 the ultimate value was found to be the minimum as compared to the other varieties, though in the early vegetative stage it recorded a higher bark value of 1·620 gms than JRO-632 and JRO-630 thereby indicating the different rate of bark formation at different stages of growth. The rate of bark formation markedly increased from the bud stage onwards and continued in the pod stage. From the performance seen in the pod stage, JRO-632 showed the maximum weight of bark, which was indicative of its greater potentiality of fibre formation.

The variations in the wood weight followed with that of bark weight, which was expected as both the components were formed simultaneously by the activity of the cambium. From the above values it was, therefore, seen that JRO-632 showed the best performance in bark formation, closely followed by JRO-620.

Percentage of bark formation on total dry weight:

The total dry weight which comprised the bark and wood weight, would naturally vary with the production of the above two components. As mentioned before, the fibre is contained in the bark region so further analysis of the values with respect to their contribution towards the growth as recorded by total dry weight would be helpful for assaying the merits of the different varieties. The percentage values of bark on total dry weight at different stages of growth have been tabulated in table V.

TABLE V

Showing variations in percentage bark formation on total dry weight at different stages of growth in *Olitorius* var.

Age in days and different stages	51 days (Vegetative)		72 days (Bud stage)		93 days (Flowering)		121 days (Pod stage)	
	Dry wt.	%Bark	Dry wt.	%Bark	Dry wt.	%Bark	Dry wt.	%Bark
JRO-632	2·683	56·17	8·274	51·11	15·769	50·95	36·86	45·86
JRO-620	1·929	49·46	8·503	49·65	13·992	53·36	33·964	45·40
JRO-753	2·938	62·22	8·567	49·13	14·634	54·54	27·764	47·00
R-26	2·942	55·06	9·16	50·59	11·259	47·22	29·656	40·44

The percentage values showed that more than 50% of the total dry weight of the plant was due to bark formation in the early vegetative, bud and flower stages of the growth, which was reduced to about 45% in the pod stage. This decrease

as was noted before, was due to increase in wood weight due to later processes of lignification and impregnation of the xylem cell walls. The percentage bark in the pod stage in all the varieties—JRO-632, JRO-620 and JRO-753, showed equal performance except R-26, which showed better performance in the early stage, but gradually decreased in later stages of growth. As expected JRO-632 showed the best performance, which was also known to be a improved variety giving higher yield.

Percentage distribution of bark :

The values obtained for the whole stem as described above have been further followed up with respect to their distribution in bottom, middle and top portions of the stem, which was important from commercial point of view. The results have been tabulated in table VI.

TABLE VI

Showing percentage distribution of bark in bottom, middle and top regions of stem, in terms of total bark weight of the whole length of the stem in *olitorius* varieties

Age in days and different ages	51 days (Vegetative stage)			72 days (Bud stage)			93 days (Flowering stage)			121 days (Pod stage)		
Stem	B.	M.	T.	B.	M.	T.	B.	M.	T.	B.	M.	T.
JRO-632	53 35	31·32	15·33	60·59	25·81	13·60	51·68	34·48	13·84	51·89	31·29	16·82
JRO-620	56·08	30·42	13·00	51·75	31·24	17·01	48·26	33·49	18·25	47·41	33 73	18·86
JRO-753	55·58	34·35	10·07	57·07	32·79	10 14	54 98	32·64	12·38	48·26	35 28	16·45
R-26	56·42	30·93	12·65	52·22	29·81	17·97	52·06	38·87	14·07	49·36	33·81	16 83

B—Bottom ; M—Middle; T—Top.

The concentration of bark in the bottom, middle and top regions of the stem showed the same picture as that of *capsularis* varieties, described before. The *olitorius* varieties also showed that about 50% of the bark formed was found in the bottom portion and 33% in the middle. while top showed about 16% bark. The nature of growth, therefore, was found to be on the whole similar with varietal differences. The ratio of bark to wood formation was also found to be similar, that is in the ratio of 1:1, in the active growing apical region. The ratio decreased in the basal regions due to increase in wood weight as described before.

DISCUSSION

The results described here in case of certain varieties of *Corchorus capsularis* and *Corchorus olitorius* at different stages of growth, indicated the physiological nature of the variations in the formation of bark and wood, the two main constituents of the total dry matter formed in a jute plant stem. The previous results on D-154 (*Capsularis*) and Chinsura Green (*olitorius*) have been published (Kar & Desarkar, 1954, 1957) bringing out the specific differences and the results discussed here

concerned the other important varieties. The addition of dry matter is the best indication of the growth of the plant and in jute we are concerned with the variations of dry matter in the plant stem, and its distribution in the bark and wood portions. The variation in weight showed that the amount of dry material (bark and wood) towards the apical region gradually increased with the growth of the main stem in height. In any particular region or level of the stem, the dry material increased with the advance of the growing season. The above tendencies have been recorded in both the *capsularis* and *olitorius* varieties,with specific and varietal differences. During the early vegetative stage, the production of bark by dry weight was found to be more than that of the wood but in later stages, the wood weight increased a little. This increase may not be due to more wood formation, but it may be due to the secondary wall thickening, lignification and impregnation of the cell walls of the xylem vessels in the wood region. The two components (bark & wood) were found to be formed as a result of closely integrated growth process due to the activity of the cambium (Kundu 1944). Therefore, the ratio of bark to wood formation was found to vary with in a very limited range (Kar & Desarkar 1957). It has been seen that by tracing the growth of these two important growth components during the life-cycle of a plant, the nature of the varieties and their performance have been more clearly understood than by mere recording of height and basal diameter. It was seen that marked changes accurred during the passing over phase of the vegetative growth towards the initiation of the flowering stage, which was no doubt coordinated with the cambium activity. The production of bark and wood by dry weight increased appreciably during this transition phase and continued to show increased growth during the flowering stage. Definite indication as to the probable performance of a variety was obtained only when the growth during the various stages was known and analysed. Amongst *capsularis* varieties JRC-212 showed an uniform growth, throughout showing its high potentiality. JRC-13 which showed vigourous growth in the vegetative stage, however, showed slow growth in the later stages. Amongst the *olitorius* varieties JRO-632 showed an uniform rate of growth throughout, by which its high yielding capacity was indicated. R-26 which showed a good growth in the early stages showed a very poor growth in the later stages.

Further analysis of the quantitative formation of bark was obtained on the percentage basis of the total dry weight. The percentage of bark weight was found to be maximum in the early vegetative stage, when compared with the total dry weight at that stage in both the species. This maximum value decreased in the later stages, thus showing that the materials, other than bark were formed, and the rate of their formation increased progressively during the season of course varying in the two species. The distribution of bark in the bottom, middle and top portions of the stem showed maximum concentration of bark in the bottom regions in both the species. But in *olitorius* var. the middle region showed more bark than in the same region of *capsularis* var. This fact indicated the nature of growth of the components in relation to length and basal diameter of the two species. (Kar & Desarkar 1957, Kar 1959).

In the varieties investigated here, though very marked difference in bark and wood growth were not recorded amongst the varieties, yet clear indications as to their rates of productions during the life-cycle of a plant were clearly recorded. The growth and development of bark and wood are among the most important features of the jute plant, because they have a direct effect on fibre development.

SUMMARY

The following varieties of *Corchoru capsulariss*--JRC-13, JRC-212 and JRC-321 and of *Corchorus olitorius*—JRO-632, JRO-620, JRO-753 and R-26 were investigated with

reference to the variations in formation of bark and wood two important consti tuents of the total dry matter formed during the course of growth and development. The results have been discussed under important phases of growth like vegetative, bud, flower and pod stages and the results have been summarised as follows :—

(I) Periodic estimations of different growth components like moisture content, total dry matter produced ; bark, fibre and wood formations, have been made throughout the life-cycle of the plant, at different stages and along the length of the stem.

(2) The sequence of, changes showed a definite tendency in both *capsularis* and *olitorius*. The amount of bark was found to be greater in the bottom regions and it gradually decreased towards the apex. But the rate of formation in the two species was found to be different in the different phases of growth.

(3) In the bottom regions of the vegetative stage, the dry weight of the bark was found to be higher in *capsularis* than in *olitorius*. In the later stages, however, the *olitorius* varieties showed higher values in subsequently formed zones at higher levels on the stem.

(4) The weight of wood increased in the late flowering and pod stages, due to the secondary thickening, lignification and impregnation of the xylem cell walls. This has resulted in changing the bark and wood ratio when compared with that of early vegetative stage. The variation, however, was found to be of a very limited range due to the integrated process of the production of bark and wood by the actvity of the cambium.

(5) Marked changes in the rate of formation of bark and wood was nioticed during the transition phase from vegetative to the flowering stage.

(6) By tracing the production of different growth components, through out the life-cycle of the plant, a better appreciation of the nature of the different varieties was obtained.

(7) Some of the varieties from both the species of *Corchorus capsularis* and *Chorchorus olitorius*, showed different vigour of growth at different stages. This helped in the assay of the fibre production potentiality of the different varieties. JRC-212 (*capsularis*) and JRO-632 (*olitorius*) both improved varieties, showed on the whole an uniform rate of growth amongst the other varieties.

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ON THE RELATIVE RESISTANCE OF SOME NATIONAL PUSA VARIETIES OF WHEAT TO *SITOTROGA CEREALELLA* OLIV. (GELECHIDAE : LEPIDOPTERA)

By

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INTRODUCTION

Recently Chatterji (1955) studied the relative resistance of fifteen National Pusa varieties of wheat (NP 760, NP 715, NP 710, NP 761, NP 721, NP 775, NP 720, NP 781, NP 782, NP 745, NP 52, NP 758, NP 764, NP 165 and NP 737) to *Trogoderma granarium* Everts. This paper deals with the natural resistance or susceptibility of the same varieties to the attack of *Sitotroga cerealella* Oliv., another pest of stored wheat.

MATERIALS AND METHOD

A pure culture of the test insect was obtained in the laboratory from a single pair of *S. cerealella* on wheat variety NP 758. Fifty adults of *S. cerealella* were introduced in wide-mouthed bottles of about half a kilogram capacity. Each of these was fitted with wire gauze screw caps and contained 100 gms. of different wheat varieties. The initial moisture content of different varieties varied between 8·87% and 11·98%. The lowest and the highest percentages of moisture were in the case of NP 715 and NP 165 respectively. There were five replications for each variety. These were kept under observation under conditions of normal room temperature during the months of June, July and August with the maximum varying from 25·5°C to 39·7°C, minimum from 24·4°C to 32·7°C.

At the end of the experiment, the loss in weight and the percentage of damaged seeds were worked out. Firstly, the final loss in weight was obtained by reweighing the contents of each bottle after separating the insects. For calculating the percentage of damaged seeds, the contents of each of the replicated bottles were emptied separately and spread out uniformly on a sheet of paper and the grain layer was divided into an equal number of squares. From random samples of hundred seeds each taken from these squares, the actual number of damaged seeds was counted. Out of these, completely bored grains from which the adults had emerged were counted separately and the rest were immersed in a beaker (1000 cc capacity) containing 700 cc of water. The damaged grains being lighter floated on the surface of water. These grains were further disected and examined under binocular microscope for confirming the presence of any immature stage. Thus the damaged seeds were counted and their percentage was calculated.

RESULTS AND DISCUSSION

The data on the two main points of examination *viz.*, (*i*) loss in weight and (*ii*) percentage of damaged grain in respect of each variety were statistically analysed and the results are presented in the following table.

TABLE 1

The analysis of the loss in weight and percentage of damaged seeds in different varieties

Wheat varieties	Percentage of moisture content	Average % age of damage in 5 replication	Wheat varieties	Percentage of moisture content	Average loss in weight in grams in 5 replications
NP 760	9·58	4·0	NP 760	9·58	2·0
NP 715	8·87	4·0	NP 715	8·87	2·2
NP 710	9·05	4·2	NP 710	9·05	2·4
NP 782	10·92	5·6	NP 761	10·82	3·0
NP 721	10·48	5·6	NP 721	10·48	3·0
NP 720	10·92	5·8	NP 775	11·48	3·0
NP 758	11·73	5·8	NP 720	10·92	3·2
NP 52	10·25	5·8	NP 781	10·80	3·2
NP 761	10·82	6·0	NP 782	10·92	3·2
NP 781	10·80	6·0	NP 745	11·48	3·4
NP 775	11·48	6·4	NP 52	10·25	3·4
NP 737	11·79	7·0	NP 758	11·73	3·8
NP 745	11·48	7·0	NP 764	11·06	4·0
NP 165	11·98	7·6	NP 165	11·98	4·0
NP 764	11·06	7·8	NP 737	11·79	4·2

The procedure was the same as followed earlier by Samuel and Chatterji (1953).

'F' test highly significant	'F' test highly significant
$SE_m = \pm 0{\cdot}2$	$SE_m = \pm 0{\cdot}1$
C. D. at 5% = 0·7	C. D. at 5% = 0·3
C. D. at 1% = 0·9	C. D. at 1% = 0·4

(*i*) *Loss in weight* : 'F' test in this case shows differences in the varieties to be highly significant. At 1% level, the varieties NP 760, NP 715 and NP 710 are superior to other varieties, the loss in weight being less. These varieties do not differ among themselves. The varieties NP 761, NP 721, NP 775, NP 720, NP 781, NP 782, NP 745 and NP 52 do not differ significantly from each other but are significantly better than NP 764, NP 165 and NP 737. The variety NP 758, however, does not differ significantly either from NP 745, NP 52 or from NP 764, NP 165 and NP 737, the latter three varieties being highly susceptible.

(*ii*) *Percentage of damaged grain* : 'F' test shows highly significant differences among the varieties. Out of the fifteen varieties included in the table, at 1% level,

the varieties NP 760, NP 715 and NP 710 are significantly resistant, showing less percentage of damaged grains, compared to the varieties NP 782 to NP 764. The varieties NP 782, NP 721, NP 720, NP 758, NP 52, NP 761 and NP 781 do not differ significantly among themselves and are neither very resistant nor very susceptible to the pest. The variety NP 775 does not differ significantly either from varieties NP 782 to NP 781 or from varieties NP 737 and NP 745. The most susceptible varieties are NP 737, NP 745, NP 165 and NP 764 and that these varieties do not differ significantly among themselves.

None of the varieties seems to be completely free from the attack of *S. cerealella.* It is, however, possible to arrange the different varieties into three fairly distinct groups according to their degree of resistance to the pest. The most resistant varieties with respect to loss in weight and percentage of damaged grain are NP 760, NP 715 and NP 710. The least resistant varieties with respect to (*i*) loss in weight are NP 758, NP 764, NP 165 and NP 737 and (*ii*) percentage of damaged grain are NP 737, NP 745, NP 165 and NP 764. The rest of the varieties stand in between the two extremes. It is significant to note that the resistant varieties *viz.*, NP 715, NP 710 and NP 760 contain lower initial moisture content *i.e.*, 8·87, 9·05 and 9·58% respectively and the least resistant ones *viz.*, NP 764, NP 737 and NP 165 contain comparatively high initial moisture content *i.e.*, 11·06, 11·79 and 11·98% respectively. The percentage of moisture content cannot, however, be taken as the sole criterion for rendering a variety more resistant or susceptible, because the varieties NP 761, NP 720, NP 782 and NP 775, having comparatively high moisture content *i.e.*, 10·82%, 10·92%, 10·92% and 11·48% respectively, do not show higher susceptibility.

The results tend to show that the degree of resistance or susceptibility of different varieties of wheat may also depend to some extent on the inherent testa hardness. It is evident that the least hard variety NP 737 falls within the more or less susceptible group. The percentage of moisture content (11·79%) is next to the highest in this variety. The hard and bold variety NP 165 also falls within the same susceptible group, having the maximum moisture content 11·98%. Though the latter is a hard variety, *S. cerealella* does more damage to it, due to its having the highest initial moisture content and also because the grains are bold. Out of the other hard varieties; NP 715, NP 710 and NP 760 are more or less resistant ones belonging to the least moisture content-group having 8·87, 9·05 and 9·58% respectively. Although NP 764 is hard, it falls within the susceptible group due to its having quite a high initial moisture content (11·06%). Further, the varieties NP 720 and NP 781 occupy the intermediate position between more or less resistant and susceptible varieties, their moisture content is also in between the two extremes. The position of the remaining varieties is not clearly defined. Probably it is a combination of the factors discussed above, together with some other factors like the protein and starch contents in these varieties, which ultimately determines the relative resistance or susceptibility of a variety to the attack of *S. cerealella.*

SUMMARY

Fifteen National Pusa wheat varieties (NP 760, NP 715, NP 710, NP 761, NP 721, NP 775, NP 720, NP 781, NP 782, NP 745, NP 52, NP 758, NP 764, NP 165 & NP 737) are compared for their relative resistance or susceptibility to the attack of *Sitotroga cerealella* Oliv. No variety is completely resistant to the attack of *S. cerealella.* The varieties NP 760, NP 715 and NP 710 are more resistant and the varieties NP 764, NP 737 and NP 165 are more or less susceptible. The rest of the nine varieties occupy the intermediate position between these two extremes.

Probably a combination of different factors *i.e.*, inherent rind hardness, protein and starch content and relative initial moisture content of wheat determines the resistance or susceptibility of a variety to the attack of this lepidopterous pest.

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EMBRYOLOGY OF *EUGENIA FRUTICOSA* L.

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The very interesting occurrence of polyembryony in the genus *Eugenia* has made this plant fascinating to the students of morphology. Tiwary (1926) reported the occurrence of polyembryony in *E. jambolana*. According to him the most prolific source of origin of several embryos is the nucellus at the micropylar half. After him Pijl (1934) gave an account of several species of *Eugenia* from Java. He could not find polyembryony in *E. jambolana* but noted the abundant occurrence of the same in *E. jambos* and *E. malaccensis*. Johnson (1936) noted a high degree of polyembryony in *E. hookeri*.

Eugenia fruticosa was not examined embryologically before and has been worked out by the present author with a view to studying its polyembryonic nature, to see the fate of the egg and the relationships of this plant with the other species of *Eugenia* as well as with the plants of the related families.

MATERIAL AND METHOD

Material of *Eugenia fruticosa* was collected from a labelled tree at the Indian Botanic Gardens, Sibpur, Calcutta. Once post-fertilized flowers were collected in the third week of April, 1953 and later another vial of the pre-fertilized flowers was obtained in the last week of March, 1955. Sections were cut at 10—12μ thickness and stained with Haidenhain's iron-alum haematoxylin.

OBSERVATIONS

Anther

To begin with, the anther arises as a protuberant mass of undifferentiated cells (Fig. 1) in which, soon after, the archesporium distinguishes sub-hypodermally. The latter divides promptly to form a number of sporogenous cells (Fig. 2). The wall of a young anther lobe shows four to five layers of cells (Fig. 3). The epidermis is composed of tangentially elongated cells, but smaller at the point of dehiscence which lies between the two adjacent anther lobes. In the mature anther the epidermal cells first lose their nuclei and cytoplasm and later persist as a layer of collapsed cells above the endothecium (Fig. 4).

The endothecial cells elongate considerably except for the region of dehiscence. They acquire radial thickenings when mature. A couple of endothecial cells at the point of dehiscence remain small and devoid of radial thickening (Fig. 4 *d*). This facilitates the rupture of the anther at this point (Fig. 5). All the cells ultimately lose their nuclei although in a few they may persist for a long time.

The middle layers are composed of narrow elongated cells, which are crushed out later by the enlarging endothecium. The tapetal cells are binucleate and rich in cytoplasm and are of the glandular type.

The sporogenous cells repeatedly divide so as to increase the number of spore mother cells before the onset of meiosis (Fig. 3). Degeneration of a few microspore mother cells is also observed. When the microspores are formed, the cells between the adjacent anther lobes obliterate so that a common chamber results.

The pollen grains are triangular in shape and show three germ pores and three germinal furrows on the periphery. These are shown in different angles in figures 6 to 11. The intine is thin and protrudes out of the germ pores. The exine is thick and smooth.

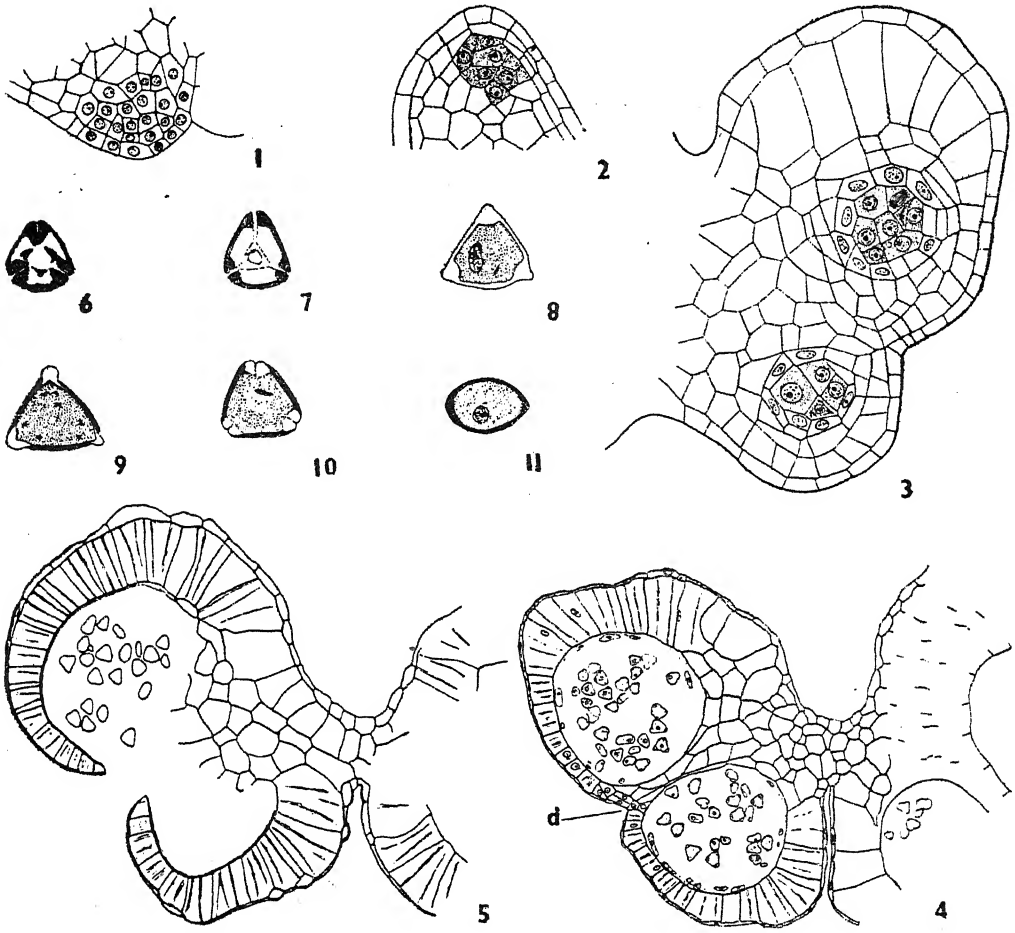


Fig. 1. T. s. young anther lobe. X 326.

Fig. 2. T. s. anther lobe showing a group of sporogenous cells bounded by an epidermis and one or two parietal layers. X 326.

Fig. 3. T. s. anther lobe showing division of sporogenous cells and wall layers ; degeneration of a few sporogenous cells is also seen. X 326.

Fig. 4. Anther lobes showing region of deniscence (*d*) ; endothecial cells showing radial thickenings. X 135.

Fig. 5. C. s. dehisced anther. X 135.

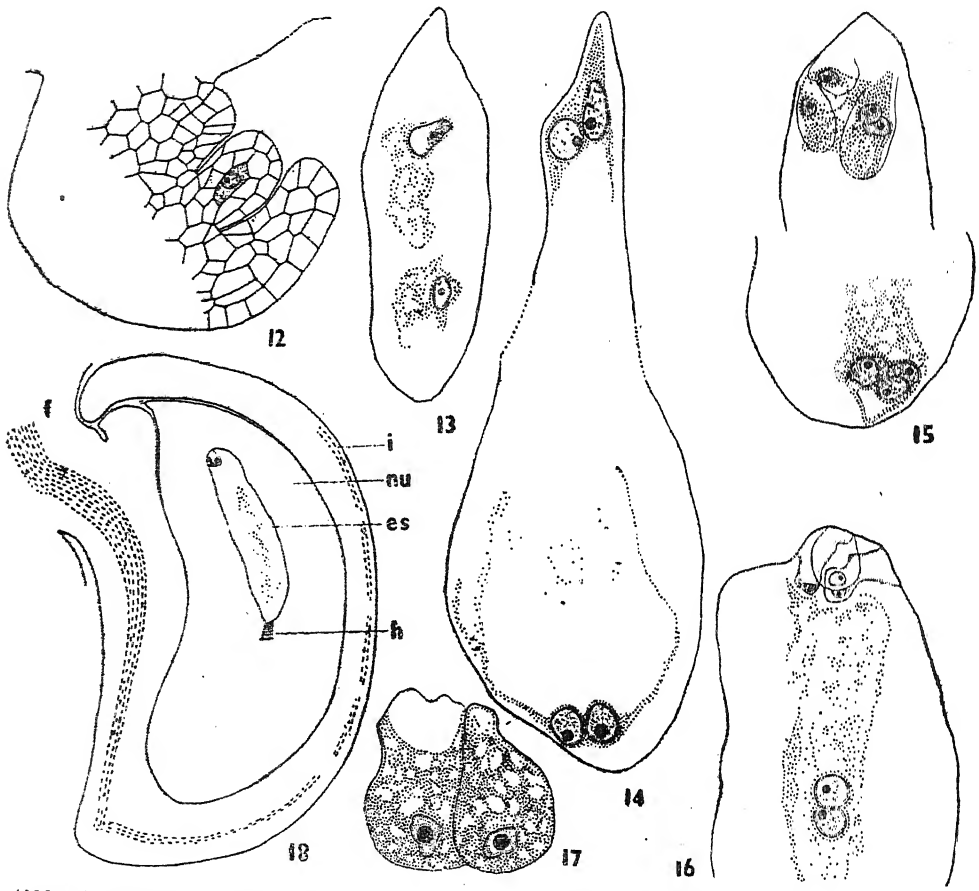
Figs. 6-11. Pollen grains showing structural details. X 652.

Megasporogenesis, female gametophyte and the ovule

During formation of the integument the ovule curves as usual. The archesporium is sub-hypodermal and functions directly as the megaspore mother cell which is clearly distinguishable from the surrounding nucellar tissue by its larger size (Fig. 12). It becomes deep-seated owing to the formation of parietal tissue.

Meiosis is normal and the chalazal megaspore functions as usual. By three successive mitotic divisions of the functioning megaspore nucleus, a normal 8-nucleate embryo sac is formed (Figs. 12 – 15).

The mature embryo sac is five-nucleate owing to the early obliteration of the antipodal cells (Fig. 16). When young the egg and the synergids appear similar in structure, but the difference becomes obvious later. The synergids are pyriform in shape and show apical nuclei and basal big vacuoles. They may not show any definite hook (Fig. 17). The egg remains scantily cytoplasmic, pyriform and smaller than the synergids.



(Abbreviations used—*d*, dehiscence ; *es*, embryo sac ; *h*, hypostase ; *i*, integument ; *nu*, nucellus ; *nu emb*, nucellar embryo ; *n end*, nuclear endosperm)

Fig. 12. L. s. young ovule showing sub-hypodermal archesporial cell. X 360.

Figs. 13-16. Stages in the development of female gametophyte. Fig. 16 shows only the upper half of *e.s.*, lower half not drawn because it contained no nuclei. X 592.

Fig. 17. Synergids. X 300.

Fig. 18. L. s. ovule at pollination. X 360.

The ovule is unitegminal and crassinucellar. The anatropous ovule at maturity is bent towards the raphe. Figure 18 shows the structure of the ovule at fertilization. The funicle is broad though short and traversed by a single vascular trace which goes half way up the integument. The portion of the integument away from the funicle grows more and overarches the part from the funicular side, and the micropylar canal is somewhat curved. The micropylar passage is narrow but widens at the tip of the nucellus. The integument shows generally six layers of cells.

The organized embryo sac is delimited by about three layers of nucellar cells at the top and several layers of cells below. In some ovules, below the embryo sac a strand of cells arranged more or less in radial rows could be distinguished but its cells were not thick-walled and were crushed out soon by the growing embryo sac (Fig. 18 *h*). This feature can be considered as the forerunner for the formation of the hypostase found in other plants of the family. The cells of the strand near the embryo sac are narrower than those at the distal end. The nucellar cells on both sides of the strand are radially elongated.

Endosperm

The primary endosperm nucleus divides repeatedly to produce a large number of free nuclei (Fig. 19). First, the nuclei are scattered irregularly throughout the embryo sac; later they become arranged in a peripheral layer around a central vacuole. A large number of free nuclei accumulate at the chalazal end imbedded in a dense mass of cytoplasm. The number of nuclei increases rapidly and fusion amongst them results in the formation of giant nuclei containing several nucleoli (Fig. 20). Gradually wall formation starts from the micropylar end and the whole endosperm soon becomes cellular except at the chalazal extremity (Fig. 24). This portion remains free nuclear for a long time.

Embryo

Fertilization is presumed to be normal, both the synergids degenerating soon after the process. The zygote may also degenerate sooner or later. Unlike *Eugenia jambolana* sometimes a proembryo may be formed from the fertilized egg (Figs. 21, 22). But mostly the nucellar embryos predominate crushing out the zygote at one stage or the other (Figs. 23, 24). The zygotic embryos show regular arrangement of their cells while in the nuceller ones no definite arrangement of the same is maintained right from the beginning. Moreover the zygotic embryos show the presence of short suspensors which the nucellar embryos lack.

The development of adventive embryos conforms to that reported for *Eugenia jambos* (Pijl, 1934). Individual nucellar cells become differentiated from the rest by the accumulation of denser cytoplasm around a prominent nucleus (Fig. 23). Such cells undergo irregular divisions resulting in the formation of small potential embryos which project into the embryo sac (Fig. 24) and continue their development. Ultimately only one, two or three embryos survive.

Seed coat

The outer epidermis of the integument consists of cells that are smaller while those of the inner and overlying layers are tangentially elongated and contain promi-

nent nuclei and cytoplasm (Fig. 25). All the cells are flattened out and together constitute the membranous testa.

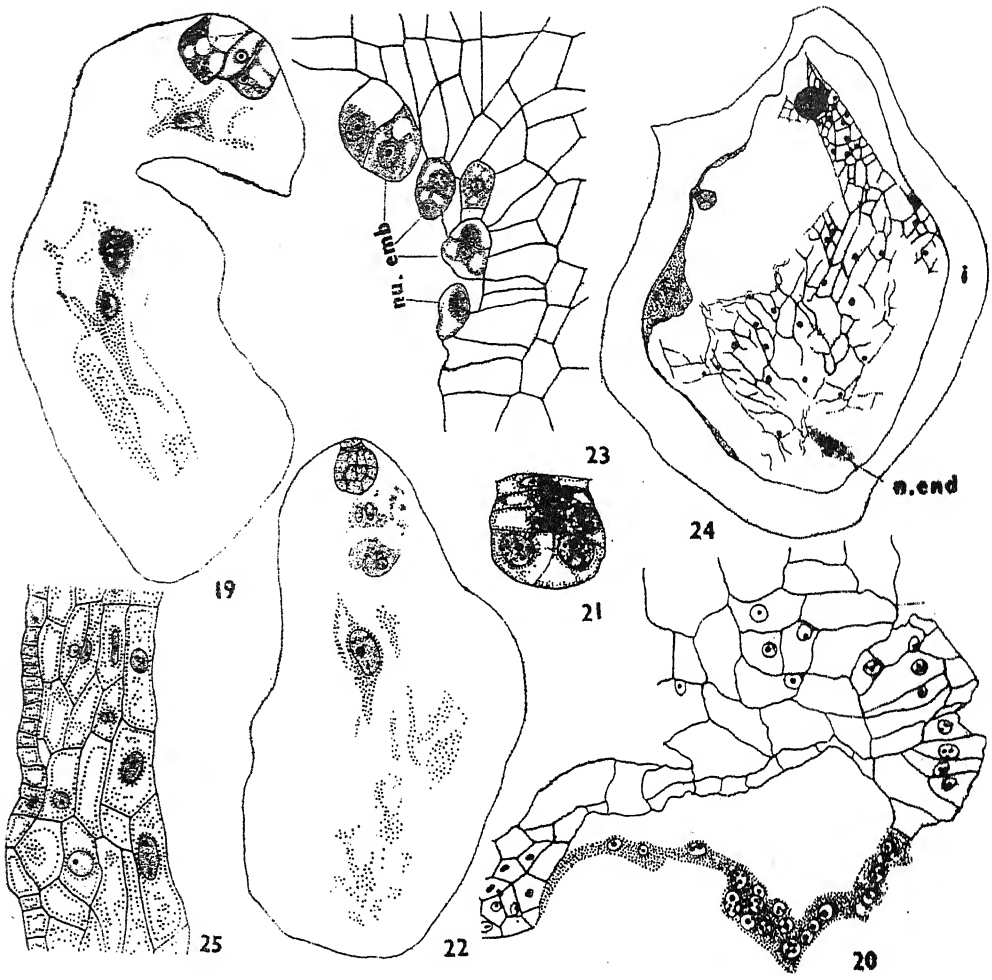


Fig. 19. Embryo sac showing degenerating synergids, egg cell and four free endosperm nuclei. X 156.

Fig. 20. Portion of endosperm from chalazal end of ovule showing cellular endosperm at the top and nuclear endosperm below. X 156.

Fig. 21. A zygotic proembryo. X 360.

Fig. 22. Embryo sac showing proembryo with short suspensor, probably zygotic in origin. X 360.

Fig. 23. Formation of nucellar embryos. X 360.

Fig. 24. L. s. ovule showing nucellar embryos ; note, a group of free nuclei (endosperm) at the chalazal end. X 60.

Fig. 25. L. s. portion of young seed coat X 360.

DISCUSSION

In the genus *Eugenia* the pollen grains vary in shape and size (Roy, 1958). They may be oval, oblong or somewhat rounded. Many are devoid of cell contents and, therefore, infertile. The mature pollen grains of *E. fruticosa* may show besides the generative nucleus a few scattered bodies in the cytoplasm which take on a stain similar to chromatin. As the vegetative nucleus has a tendency to degenerate early in the pollen grain, the chromatin like bodies may represent fragments of the former.

In *Eugenia fruticosa* the ovule is unitegminal and thus different from those of the other genera of the family and *E. bracteata* (Roy, 1955) in which it is bitegminal. The single integument does not throw any conclusive light on whether it represents a fused product of the two integuments (Mauritzon, 1939). As no trace of such a fusion at any stage of development of the ovule was noticed, it appears that the single integument perhaps represents the outer integument only ; the inner having dwindled away during the process of evolution of this species. This integument has become thick enough to allow a vascular bundle to pass through it.

Eugenia fruticosa shows the presence of a weekly formed hypostase while in other members of the family it is fully developed (Mauritzon, 1939). In *Eugenia bracteata* (Roy, 1958) the hypostase is normally formed while many other species show the absence of it. In *Cuphea lanceolata* (Mauritzon, 1934) of Lythraceae a well formed hypostase is present which gets crumpled by pressure from the growing embryo sac. This crumpled mass which projects into the embryo sac is designated as the "Postament" by Mauritzon. In the plant under investigation no such "Postament" is formed as the hypostase is weak structurally. However, but for the thickened walls of its cells the hypostase resembles a well formed one of the Lythraceae or Myrtaceae in other details. It appears that the hypostase in this plant is in a process of dwindling away; the condition being fully realized in many species of *Eugenia, e.g. E. jambolana* and *E. jambos*.

The embryo sac of *Eugenia fruticosa* has a great similarity with those of the other species of the genus. The antipodals are ephemeral like those of Lythraceae (Joshi & Venkateswarlu, 1935*a*, 1935*b*, 1936) and so the mature embryo sac is always five-nucleate. The nuclear endosperm has a similarity with those of *Melastoma* (Subramanyam, 1948), *Thymelaea* (Venkateswarlu, 1945), *Kunzea, Melaleuca* and *Callistemon* (Mauritzon, 1939) in showing a chalazal aggregation of nuclei and cytoplasm which persist for a considerable time after the rest of the endosperm became cellular.

Embryogeny in Myrtaceae is interesting. Many species of the genus *Eugenia* show polyembryony while the others do not bear any trace of it. *E. jambolana* and *E. jambos* show abundant formation of nucellar embryos (Tiwary, 1926; Pijl, 1934; Roy, 1958) while *E. malaccensis* exhibits the development of integumental embryos (Pijl, 1934). In these plants the zygote either degenerates or the proembryo fails to compete with the adventive embryos. In *E. bracteata*, however, only zygotic embryos are formed and no adventive embryo is ever to be seen (Roy, 1955). *E. fruticosa* occupies a middle position between the two extreme forms as both zygotic as well as adventive embryos have been found to develop in this species.

Development of the nucellar embryos falls in line with those of *Eugenia jambolana* and *E. jambos* (Roy, 1958). Individual cells of the nucellus in the micropylar region become distinguished by accumulation of denser cytoplasm and the prominence of nuclei. The cells undergo divisions in various planes so that any number of small potential embroys are formed. They soon begin to project into

the embryo sac and continue their development further. Finally, only a few may persist in the polyembryonic seed, others obliterating during the course of development.

SUMMARY

The archesporium in the anther appears to develop sub-hypodermally. The pollen mother cells are bounded by an anther wall of four to five layers of cells. The tapetum is of the glandular type and the cells are binucleate. The endothecial cells enlarge enormously except in the region of dehiscence of the anther. They develop radial thickenings and constitute the only surviving layer in the mature anther.

The mature pollen grain is triangular in shape with three germ pores at each corner. The exine is thick and smooth while the intine is thin and often protrudes out of the germ pores.

The ovule is anatropous with a sharp bend towards the raphe. It is unitegminal and crassinucellar and may show a weakly formed hypostase. The archesporial cell differentiates sub-hypodermally and functions directly as the megaspore mother cell. It becomes deep-seated owing to the formation of a number of cover cells. Reduction division in the megaspore mother cell is normal and a linear tetrad of megaspores results of which the chalazal one is functional.

The development of the female gametophyte is of the Polygonum type. The mature embryo sac is always five nucleate due to the ephemeral nature of the antipodals. The synergids are more prominent than the egg.

The endosperm is of the nuclear type. There is an accumulation of nuclei and cytoplasm at the chalazal end. The nuclei fuse with one another at random and thus form macronuclei with various shapes and sizes containing several nucleoli. This portion remains free nuclear for a long time when the other parts become cellular.

Zygotic embryos develop rarely. The seeds are either mono-or polyembryonate. The adventive embryos arise from the prolific nucellus.

In the end, I wish to express my sincere thanks to Prof. P. Maheshwari of the University of Delhi for facilities and encouragement.

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CYTOGENETICAL STUDIES IN SOLANUM MELONGENA L.

IV. POLLEN TUBE GROWTH[1]

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ABSTRACT

Intervarietal reciprocal crosses between two cultivated varieties *purple long* and *white round* and a wild variety *insanum* have been found to give perfect fruit set. Although the growth of pollen tubes in stigma and style have been found to be quite normal in these crosses, the number of tube bursts were comparatively more when the variety *insanum* was used as the female parent. The presence of some growth retarding substances in the conducting tissue of the style of the variety *insanum*, seems to be the possible cause of bursting.

INTRODUCTION

Bhaduri (1951) has mentioned that *Solanum melongena* var. *insanum*, a wild variety, crosses readily with cultivated varieties of *S. melongena* but produces fertile hybrids in one way cross only i.e. when *S. melongena* var. *insanum* is used as the male parent. During the present investigation a large number of crossing experiments between cultivated and wild varieties of *S. melongena* were made. Equally good results were obtained when the wild variety was used as the female parent. Naturally this led to studies of pollen tube growth because such studies are being utilised to explain the causes of self and cross incompatibilities met with in plants.

MATERIAL

For the present study the following three varieties of *S. melangena* have been selected.

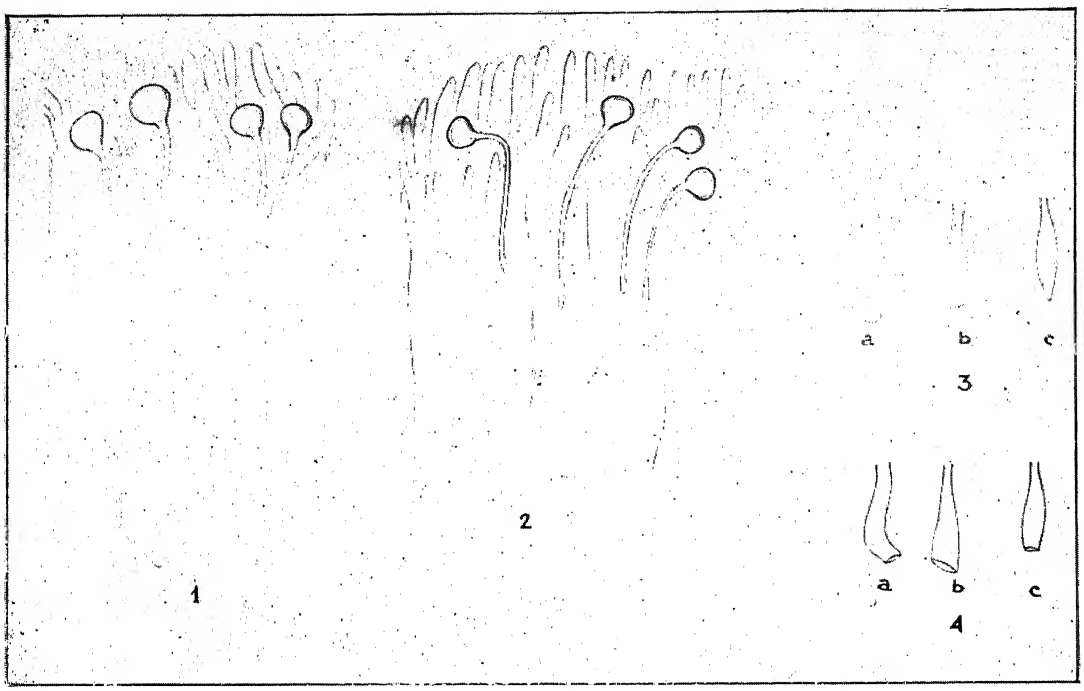
1. Var. *Purple long* (a selection from the *greenlong* variety obtained from National Botanical Gardens, Lucknow).
2. Var. *White round* (a selection from S. M. 5 obtained from Bihar Agricultural College, Sabour).
3. Vari. *insanum* (a wild variety obtained from the Indian Agricultural Research Institute, New Delhi).

METHODS

Two methods were employed for tracing the course of the pollen tube in the pistil. (1) embedding and sectioning of the pistil (Iyengar, 1938) and (2) dissecting the outer cortex of the style and staining the central strand of connecting tissue (Buchcholz and Blakeslee, 1927; Iyengar, 1938; Pande, 1955).

Flowers were pollinated at about 10-30 A.M. and fixed after 2 hours of pollination either in aceto-alcohol (1:1) or Navashin's fluid A and B (1:1). Longitudinal sections of the pistil about 12 μ in thickness were cut. Sections of the

1. A part of the thesis accepted for the D. Phil. degree of the University of Allahabad, Allahabad.



DISCRIPTION OF FIGURES

Figures 1 to 4 were drawn at table level with the aid of Reichart Camera lucida using Carl Zeiss-Jena Microscope (No. 102580) having aplanatic condenser. Figures 1 and 2 show magnification X 1030 and Figures 3 and 4, X 4100.

Fig. 1. Pollen tube growth of the variety *purple long* in Stigma and a portion of style of the variety *insanum*, 2 hours after pollination.

Fig. 2. Pollen tube growth of the variety *insanum* in stigma and style of the variety *purple long*, 2 hours after pollination.

Fig. 3. Swollen pollen tube tips, (a) round, (b) oval and (c) oblong pointed.

Fig. 4. Pollen tube tips a, b and c of the figure 3, after bursting.

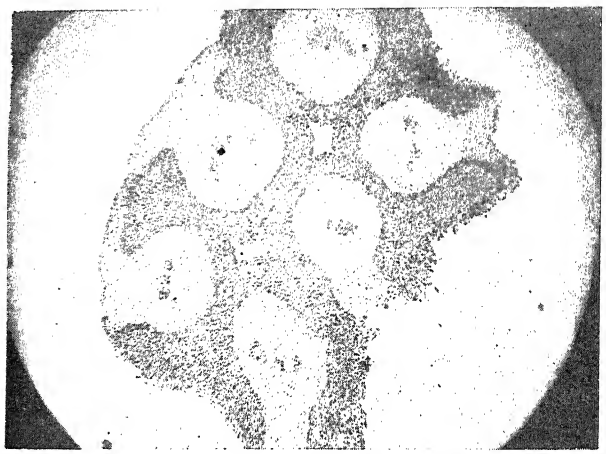


Fig. 5. Transverse section of the top of six loculed stigma with a central cavity and outgrowths of papillated cells.

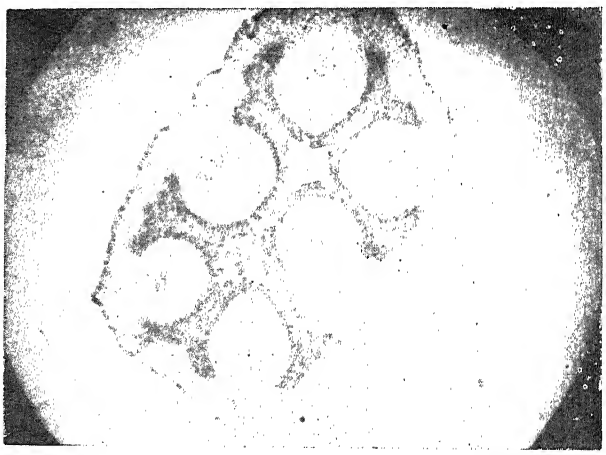


Fig. 6. Transverse section of the stigma at the level below that of the figure 5 showing centralisation of conducting tissue.

Fig. 7. Pollen tube growth of the variety *purple long* in the style of the variety *insanum*.

material fixed in aceto-alcohol were stained in 1% cotton blue lactophenol for about an hour and then transferred to lactophenol and left overnight. They were then changed to fresh lactophenol and mounted for examination. The pollen tubes take a blue colour, while the tissues of the stigma and style are almost colourless. The material fixed in Navashin's fluid were stained with crystal violet.

The outer cortical tissue was dissected for tracing the pollen tubes in the style; this was rather difficult since the length to be dissected was variable in the varieties.

The rate of growth of pollen tubes was studied also by germinating pollen grains in an artificial culture medium of 2% agar and 5% sucrose in equal parts. The tube growth was then studied over the cavity as well as plain albuminised slides.

OBSERVATION

Structure of the pistil:

The varieties under investigation have solid pistils. They have a distinct ovary made up of 5-7 locules, a style ranging from 6 to 11 m.m. in length and a stigma with 5-7 locules (Fig. 5). The length of stigma also shows minor variations in the varieties. The number of loves in the stigma and the number of locules in the ovary are in close numerical correspondence with each other. The stigma has a central cavity (Fig. 5). As one proceeds down the stigma; the conducting tissue becomes apparently limited to the central area (Fig. 6).

The papillated cells of the stigma appear peculiarly bulged and assume various shapes. Stout and chandler (1933) in *Hemerocallis* report the presence of protuberances in the papillate cells of the stigma covered with mucilage for supplying moisture to the germinating pollen grains. Martin (1913) in *Trifolium* shows the cutinisation of exposed portions of papillate cells of the stigma. The presence of starch grains in the papillate cells of the stigma and difference in shape of starch grains in the pollen grains have been taken advantage of by some to identify the nature of the pollen tubes in the pistil (Renner, 1919; Lang, 1937; Iyengar, 1938).

In the style the cortical tissue occupies a slightly greater area than in the stigma, the conducting tissue being still limited to the centre. The number of vascular strands in the ovary depends upon the number of locules. The placentation is axile and the ovules are orthrotropous.

POLLEN GRAINS

The pollen grains of all three varieties *purplelong*, *insanum* and *whiteround* are *tricolporate* with hard exine (Figs. 9 and 10). Their average size ranges from 20·83 to 25·13 μ in the varieties *purplelong* and *whiteround* and from 17·68 to 21·80 μ in the variety *insanum*. The pollen grains of all the three varieties, when completely mature are dull in appearance and are powdery. Pollen grains at the time of shedding are full of starch grains and stain deep blue with iodine potassium iodide solution. The exine of the grain has been found to be resistant to concentrated HCl.

GROWTH OF POLLEN TUBES IN THE PISTIL

The formation of pollen tube begins immediately after the deposition of the pollen grain on the stigma, through any of the four pores. Fig. 1. shows the

growth of pollen grains of the variety *purplelong* in stigma and style of the variety *insanum*. Fig. 2 shows the growth of *insanum* pollen grains in stigma and style of the variety *purple long*. The percentage of tube formation is about 75.

TABLE I

Pollen tube length in μ in the artificial, selfed and intervarietal crossed flowers of *Solanum melongena L.*, after 2 hours of pollination

parents ♂ \ ♀	Tube length in μ (average of 30 readings)		
	Var. purple long	*Var. insanum*	*Var. whiteround*
Var. *purplelong*	260·52	212·75	236·35
Var. *insanum*	238·45	251·65	240·32
Var. *whiteround*	242·54	216·65	246·54

From the table it is apparent that especially in the varieties *purple long* and *insanum* the tube growth is *significantly* greater when artificial selfing was resorted to. In artificial intervarietal crosses, the growth of the tube (Figs. 7 and 8) does not interfere with successful fruit setting as is evidenced by the fairly high percentage of fruit set in these crosses at the field scale.

Some granular material was seen in the pollen tubes, the nature of which could not be made out. The migration of reserve substances of the pollen grain have been reported by Renner (1919), Brink (1924), Gore (1932), Iyengar (1938) and Beck and Joly (1941).

One of the interesting phenomena observed is the dilation of the growing tips of the few tubes in the style assuming various shapes e.g. round, oval and oblong pointed (Figs. 3 and 11). The length of the tube affected is about 40 μ from the tip. In some cases the swollen tips burst and the cytoplasm is ejected leaving the tubes empty (Fig. 4). The frequency of the formation of such swollen tips and their bursting in selfed and intervarietal crosses is quite small. But when the variety *insanum* is used as the female parent, the formation of swollen tips is increased. Buchcholz and Blakeslee (1927) in *Datura* and Anderson and Sax (1934) in *Tradescantia* have observed similar swollen tips and their bursting. Sears (1937) in *Petunia* and *Nicotiana* observed various shapes in artificial culture.

In artificial culture:

The clump of pollen grains when dusted on the culture medium on the albuminised slide spread apart so that the grains lie almost equidistant from each other. Beck and Joly (1941) also observed such phenomenon while germinating pollen grains of some monocotyledons. The pollen grains took up water from the medium, increased their volume considerably and often began to grow tubes after few minutes and attained maximum growth after 36 hours. Only one tube develops from a grain through one of the pores in all the three varieties i.e. pollen grains are monosiphonous (Figs. 1 and 8). The growth of two tubes per grain

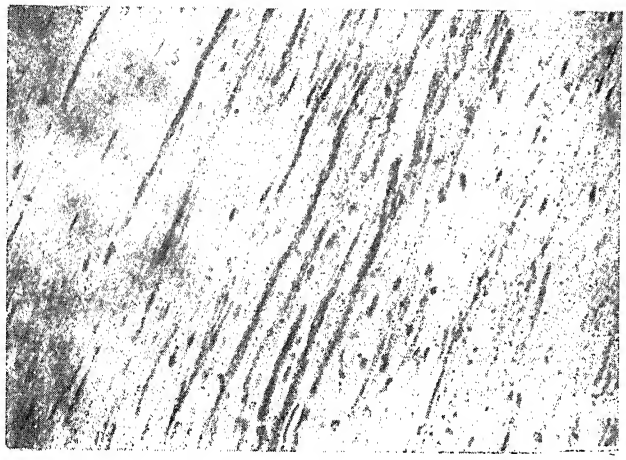


Fig. 8. Pollen tube growth of the variety *insanum* in the style of the variety *purple long*.

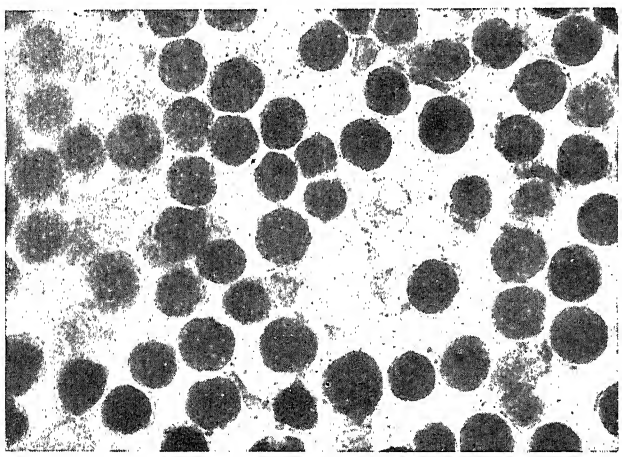


Fig. 9. Pollen grains of *S. melongena* var. *purple long*.

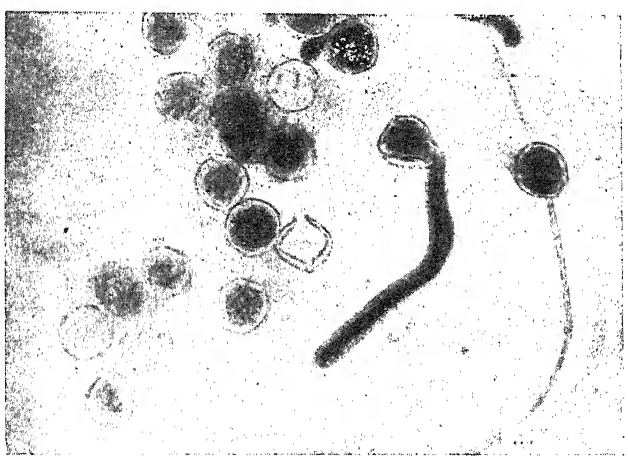


Fig. 10. Pollen grains of *S. melongena* var. *insanum* showing monsiphonous growth.

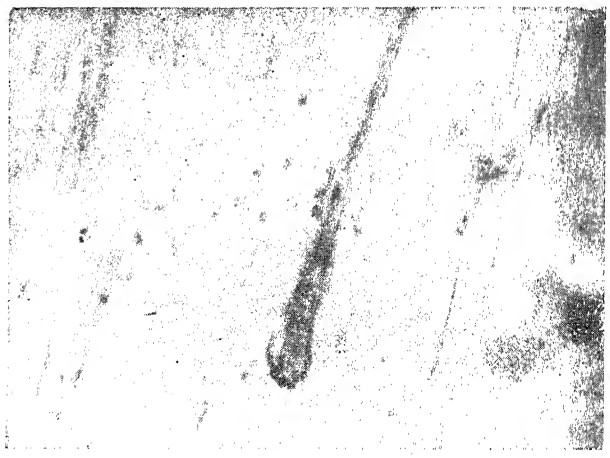


Fig. 11. Swollen round tip of pollen tube in the style.

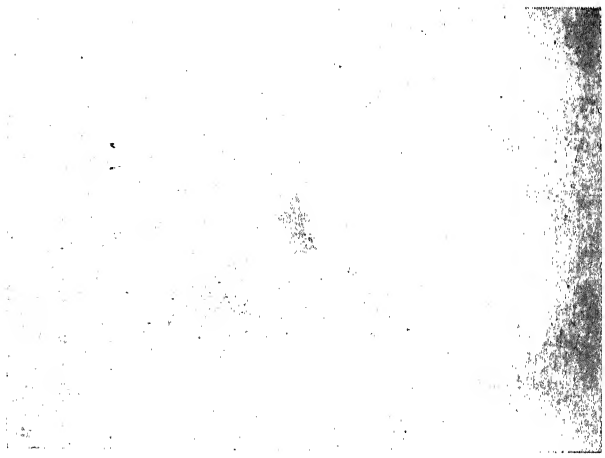
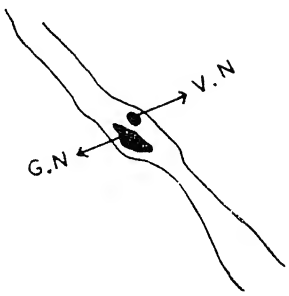


Fig. 12. Two nuclei present in the plasm of the growing pollen tube of *S. melongena* var. *purple long*.



G.N - GENERATIVE NUCLEUS
V.N - VEGETATIVE NUCLEUS

Fig. 13. Explanatory diagram of the figure 12.

(i.e. polysiphonous condition) has been reported by Lang (1937) and Iyengar (1938) in tetraploid American cotton. Beck and Joly (1941) in monocotyledons, Datta (1955) in *Corchorus* species and Verma and Verma (1957) in Malvaceae have found the polysiphonous condition when pollen grains were germinated in artificial medium containing growth promoting substances. The maximum growth of the tube is reached within 36 hours of the dusting of pollen grains on the medium smeared on the albuminised slides kept in moist chamber. The maximum growth attained is 600, 560 and 530 μ for the varieties *purple long*, *white round* and *insanum* respectively. Johri and Vakil (1937) recorded 17% germination of pollen grains of *Solanum melongena* var. *round-purple* and a tube length of 570 μ. They further noted the respective increase to 70 and 4708 when boric acid was added to the culture medium. Loo and Hwang (1944) obtained good growth of pollen tubes in monocotyledons when manganese chloride was added to the culture.

The diameter of the tube in the varieties *purple long*, *white round* and *insanum* was 20·35, 22·65 and 17·45 μ respectively. There is thus a proportionate correspondence between the diameter of pollen grains and the length of pollen tubes of these varieties.

Within the plasm of the growing tube two nuclei, a vegetative and a generative nucleus, are present (Fig. 12 and 13).

DISCUSSION

The wild variety *insanum* of *solanum melongena* L. has been found to set fairly high number of fruits when artificial crosses and reciprocal crosses with cultivated varieties *purple long* and *whiteround* were made. Bhaduri (1951) has obtained fertile hybrids only when the variety *insanum* was used as the male parent and cultivated varieties as female parents. The growth of tubes in the varieties *purplelong* and *insanum* is significantly greater when artificial selfing was resorted to. The tube length however was greater in the variety *purplelong*.

The frequency of tip swelling and bursting in the crosses is quite low but it is comparatively high when the variety *insanum* was used as the female parent. This phenomenon has been reported to be of common occurrence in interspecific crosses. Pollen tubes of *Datura meteolides* grow normally in the styles of *Datura stramonium*, but in reciprocal crosses the tube tended to swell and burst (Buchcholz and Blakeslee, 1927). Anderson and Sax (1934) found that in *Tradescantia* the ends of the pollen tubes assumed various shapes, sometimes swollen and sometimes pointed. They mentioned that there seemed to be an association between pointed ends and incompatible matings although they also noted apparent exceptions. Iyengar (1938) in cotton, noticed swollen tips and coiling of tubes in the case of pollination of American types on the Asiatic forms. Pande (1955) in *Trifolium* reported that the interference zones result in the slow growth of the tubes.

Brink (1924) adduces good evidence to show that sugar can diffuse into the tube and the hydrostatic pressure produced by it, is the sole cause of bursting in artificial culture. According to Beck (1928) and Ursprung (1929) the disbalance between the turgor and the growing rate of the tube may be responsible for bursting. Heyn (1932) and Beck and Joly (1941) are of the opinion that changes in plasticity at the tip having ceased, growth ceases in consequence, and the changes in elasticity are lacking as soon as growth ceases, so that the regularly increasing turgor must cause the tip to burst. The bursting of tubes in the style cannot be due to malnutrition which otherwise would have been observed in the

artificial medium also. The bursting of tubes on the micropyle of the ovule for the fusion of generative nuclei with the egg nucleus and the endosperm nucleus is normally the essential step in the fertilization. The bursting of tubes in the style of *S. melongena* varieties then appear to have some relation with the conducting tissue on which they run. Iyengar (1938) in cotton, has shown that during the growth, the tube gets food material from the tissue they traverse. The presence in the pistil tissue of substances, other than those present in medium might then be responsible for such bursting, which in the wild variety *insanum* appears to be slightly more antagonistic, to the pollen tubes of varieties *purple long* and *whiteround* (Table I).

ACKNOWLEDGEMENTS

I wish to record my sincerest gratitude to Dr. S. P. Naithani, Botany Department, Allahabad University, for his guidance. I also acknowledge my deep indebtedness to Dr. K. T. Jacob, Head of the Department of Botany, Bose Institute, for timely suggestions and in-estimable facilities and to Dr. D. M. Bose, Director, Bose Institute, for permission to carry out this work at the Institute.

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ON TWO CASES OF DISPLACED PROSTATE GLANDS AND MALE GENITAL APERTURES IN THE COMMON INDIAN EARTHWORM PHERETIMA POSTHUMA (L. Vaill)

By

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INTRODUCTION

Several workers have reported anomalies with respect to the number and distribution of genital papillae in earthworms including several species of *Pheretima* (Stephenson, 1930). Gates (1926) enumerated and tabulated a number of cases with displaced copulatory papillae in *Pheretima posthuma*. The present authors (1959) described 37 similar displaced organs in *Pheretima Posthuma* which were not included in Gates' tables.

The authors came across two specimens with displaced parts in the male reproductive system which are described under the following two headings.

OBSERVATIONS

I. Presence of an Accessory Prostate Gland.

Presence of accessory prostate glands in certain species of *Pheretima* has been reported by various workers in the past (Stephenson, 1930). According to Gates (1926) in *Pheretima posthuma*, there may be a single accessory prostate in any of the segments XVII, XIX and XX or there may be a pair in one of these segments. Such accessory prostates differ from the normal ones of the XVIII segment in having no vasa deferentia (Gates, 1926).

The authors have come across a specimen with an accessory prostate on the right side of segment XVII (Fig. 1), which extends behind into the segment XVIII. The prostate gland in these segments is smaller in size, and the vasa deferentia of the right side instead of extending to the normal prostate in segment XVIII, join the duct of the accessory prostate in segment XVII. The prostate gland of the same side is provided with a prostatic duct, which resembles the normal common prostatic and spermatic duct in appearance. The prostatic apparatus of the other side maintains its usual position.

The genital papillae in this specimen are absent in segments XIX. In segment XVII there is the usual papilla on the left side and on the right side it is represented by an elevation on which is situated the male genital aperture of this side (*i.e.* the aperture of the two vasa deferentia and the duct of the accessory prostate gland). In addition there is an accessory genital papilla on the left side of segment XVI. Segment XVIII shows a pair of swellings with apertures on them. It has been determined by dissection that the opening on the left side is the usual male genital aperture and that of the right side just a prostatic opening.

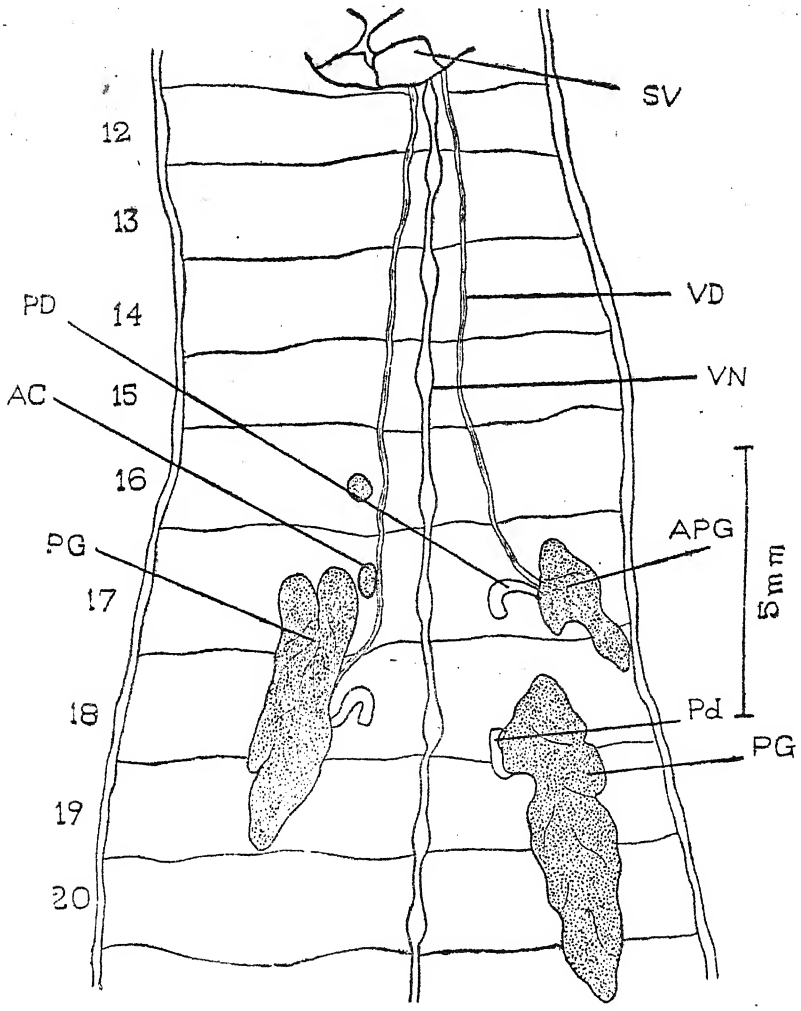

Fig. 1. Dissected Segments XII to XX of *Pheretima posthuma* showing an accessory prostate.

II. *A case of Asymmetric Male Genital Apertures.*

Gates (1926) described a specimen of *Pheretima posthuma* in which the clitellum and the male and female reproductive organs including the prostates and their ducts had shifted forward by two segments. We have come across a specimen in which the prostatic apparatus and the male genital opening have shifted forward than their usual position by two segments on one side and by two segments backwards on the other. A detailed description of the disposition of male organs of this individual is as follows.

In this specimen the male genital opening of the left side is situated in segment XVI and that of the right in segment XX, (Fig. 2). As to the genital

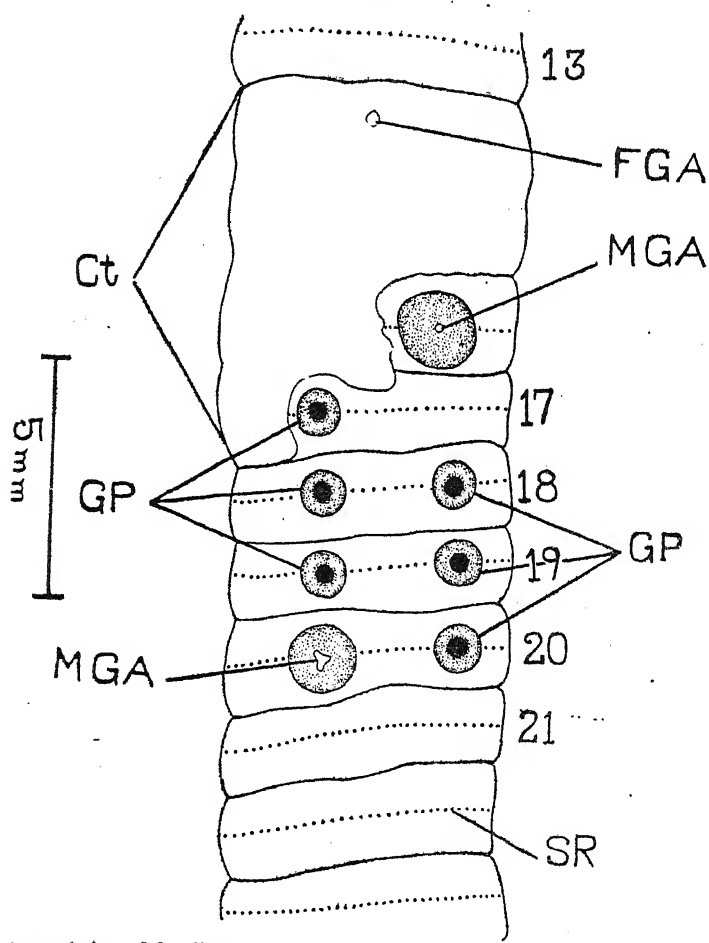

Fig. 2. Ventral view of the clitellar region and some of the neighbouring segments of *Pheretima posthuma* showing asymmetric male genital apertures.

papillae on segment XVII, the papilla of the left is absent. A pair of papillae is on its proper place in segment XIX. Additional copulatory papillae are present

on the right and left sides of segment XVIII and also one on the left side of segment XX. The clitellum in this specimen is incomplete on the left side of segment XVI around the male genital aperture. A detailed dissection of this specimen further revealed the following interesting features.

(*a*) The prostate glands are asymmetrically placed (Fig. 3.). The prostate of the right side extends from the posterior part of the XIX to the middle of segment XXII. The common prostatic and spermatic duct of this gland is present in segment XX. The prostate of the left side extends from the anterior part of the XVI to the middle of segment XVIII. The common prostatic and spermatic duct of this side is located in segment XVI.

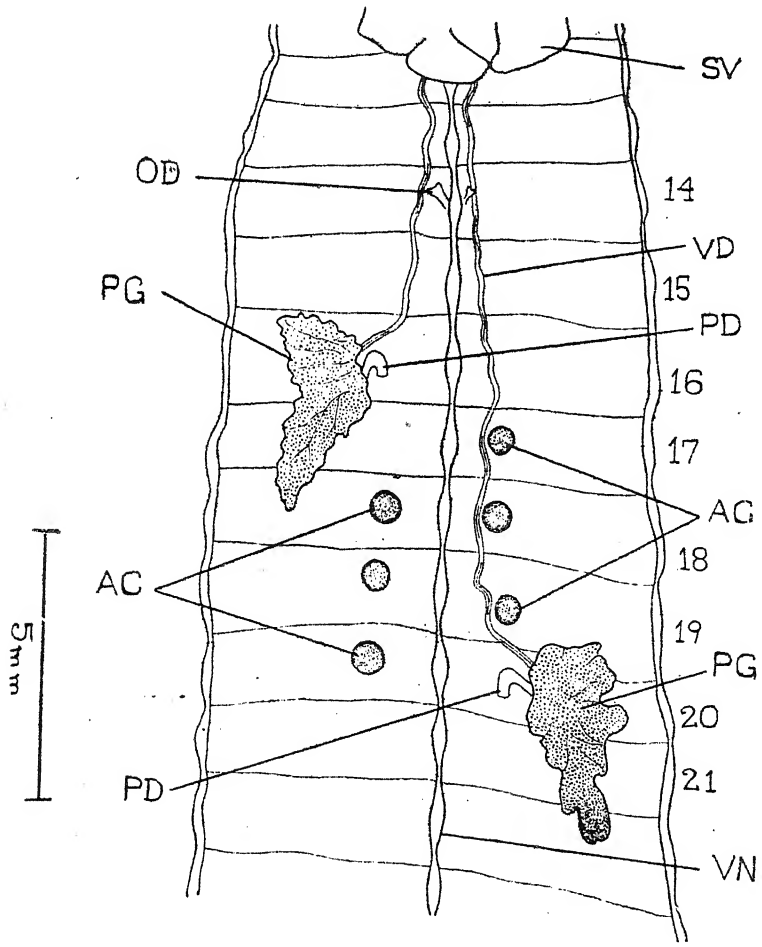

Fig. 3. A sketch of the dissection of the reproductive region of the same worm as shown in Fig. 2.

(*b*) The vasa deferentia of the right side extend up to segment XX to join the prostatic duct of this segment and those of the left side to the segment XVI to form the left common prostatic and spermatic duct in this segment.

CONCLUSION

Displacement of the following range of several parts in the male genital system of *Pheretima posthuma* is recorded.

(1) An accessory prostate may be present in any one of the segments XVII, XIX and XX or there may be a pair of them in any one of these segments. The largest number of prostates in one worm on record is five (Gates, 1926). The vasa deferentia may extend to the normal prostate as usual or to an accessory prostate.

(2) The prostatic apparatus with the male genital apertures may shift forward or backward by a few segments. In one case shifting forward by two segments (Gates, 1926) and in another specimen forward shifting by two segments on the left side and posterior shifting to the same extent on the right side (the present communication) have been described.

LETTERING OF FIGURES

AC Accessory Glands associated with Genital Papillae; APG Accessory Prostate Gland; Ct. Clitellum; FGA Female Genital Aperture; GP Genital Papillae; MGA Male Genital Aperture; OD Oviduct; PD Common Prostatic and Spermatic Duct; Pd. Prostatic Duct; PG Prostate Gland; SV Seminal Vesicles; SR Setal Ring; VD Vasa deferentia; VN Ventral Nerve Cord; 13, 14, 15, etc. Number of Segments.

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FUNGI CAUSING PLANT DISEASES AT JABALPUR (MADHYA PRADESH)—V

By

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[Received on 20th May, 1960]

Agarwal, Nema and Beliram (1959), Agarwal and Beliram (1960), Agarwal (1961) and Nema and Agarwal (1960) have described in the first four series of the paper one hundred and seven parasitic fungi occurring at Jabalpur. Twelve more deuteromycetes, which include 4 new species, one new fungus record for the country, 2 new host records and the rest new records for the state, are being described in this paper.

The number of the species are the serial numbers of the fungus flora of Jabalpur.

108. *Pyrenochaeta tandonii* Agarwal & Hasija sp. nov. on leaves of *Tephrosia purpurea* Pers., Mahakoshal Mahavidyalaya grounds, September, 1959, Leg. G. P. Agarwal.

Symptoms of the disease

The disease starts from any part of the leaf on both the surfaces. Spots are brown, circular to irregular and often coalesce increasing the diseased surface. In the same spots pycnidia of *Phyllosticta tephrosiae* Agarwal, described in the third series of the paper, were also associated.

The causal organism

Pycnidia dark brown, globose to subglobose, 50·2—98·6 μ in diameter, ostiolate, with bristles near the ostiole, bristles dark brown, nonseptate; conidia hyaline, single celled, oval to spherical, 3·9 – 6 × 2·9 – 3·5 μ. (Fig. 1).

The specimen was examined by Mr. Sutton, Assistant Mycologist, Commonwealth Mycological Institute, Kew. It is a new collection there. So far no *Pyrenochaeta* has been described on any *Tephrosia*. It is, therefore, being described here as a new species and named *Pyrenochaeta tandonii* after Prof. R. N. Tandon, Head of the Botany Department, University of Allahabad, under whose able guidance the senior author initiated his studies in Mycology.

Pyrenochaeta tandonii Agarwal & Hasija sp. nov.

Pycnidia fusce brunnea, globosa vel subglobosa, 50·2 – 98·6 μ diam., ostiolata, setis prope ostiolum, setis fusce brunneis, non-septatis; conidia hyalina, unicellulata, ovalia vel sphaerica, 3·9 – 6 × 2·9 – 3·5 μ.

In foliis *Tephrosiae purpureae* Pers. ad Jabalpur, India, Sept. 1959, leg. G. P. Agarwal.

*Lecturer in Botany, T. R. S. College, REWA.

The type specimen has been deposited in the Herbarium of the Commonwealth Mycological Institute, Kew, No. 77917 and also in the Dept. of Botany, Mahakoshal Mahavidyalaya, Jabalpur.

109. *Phyllosticta ipomoeae* Ell. & Kellerm on leaves of *Ipomoea* sp., Waterworks, November, 1959, Leg. S. K. Hasija.

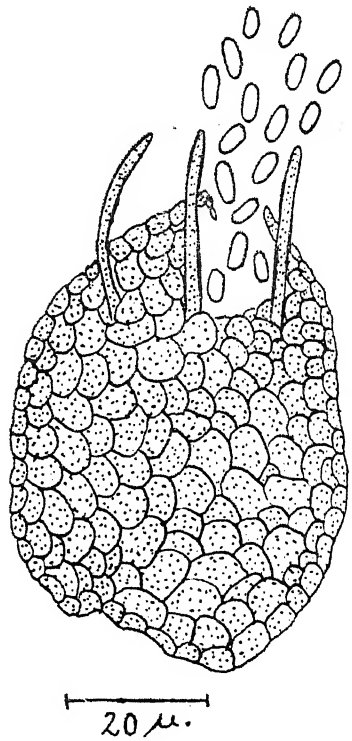

Fig. 1. *Pyrenochaeta tandonii*—Pycnidium and spores.

Symptoms of the disease

The disease first appears as dark brown pin head spots only on the upper surface of the leaf. It starts from any part, becomes circular to oval, less often angular and increases in size up to 1·5 cm. in diameter. Mature lesions are dirty white in the centre bounded by a thick dark brown margin. The central region becomes necrotic and shows the presence of abundant pycnidia as black dots. Finally the central necrotic part breaks away developing a shot hole. A single leaf shows several spots which seldom coalesce. The main veins are freely traversed.

The causal organism

Pycnidia brown, globose to subglobose, ostiolate, erumpent, 25 – 176·7 μ in diameter, average 91·5 μ; conidia hyaline, single celled, oval to spherical, 3·1 – 10·1 × 3·1 – 6·2 μ, average 6·1 × 3·6 μ.

P. ipomoeae has been reported on leaves of *Ipomoea* sp. from Kirkee, Poona by Sydow H. & P. and Butler (1916). Since then it has not been reported from any other part of India. This is a new record for the state.

110. *Phyllosticta sesbaniae* Syd. on leaves of *Sesbania grandiflora* Pers., Adhartal, January, 1959, Leg. J. S. Dubey.

Symptoms of the disease

The lesions are brown, elongate and irregular. The central region becomes ash coloured and necrotic in which appear pycnidia as black dot like structures.

The causal organism

Pycnidia dark brown, globose to subglobose, ostiolate, 43·4 – 206 μ in diameter, average 173·4 μ; conidia hyaline, single celled, cylindrical, with rounded ends, 6·9 – 13·2 × 3·9 – 4·7 μ, average 8·5 × 4·1 μ.

Phyllosticta sesbaniae Syd. has been reported on leaves of *Sesbania* sp. from Pusa by Sydow H. & P. and Butler (1916). This is the first record for the state.

111. *Phleospora cassiae* Thirum. & Narasimhan on leaves of *Cassia fistula* Linn., Waterworks, October, 1959, Leg. S. R. Chowdhury.

Symptoms of the disease

The disease first starts as brown pin head spots either from margin or leaf blade. Spots are usually irregular, aggregated and distributed on leaf blade in dark brown patches.

The causal organism

Pycnidia imperfectly formed, dark brown, globose to lenticular, ostiolate, erumpent, 49·6 – 186 μ in diameter, average 107·9 μ; conidia hyaline, narrowly elongate, nonseptate, straight or curved, with rounded ends, 15·5 – 37·2 × 2·3 – 3·1 μ, average 25·5 × 2·9 μ.

Phleospora cassiae is a new fungus record for the state. The species was first described by Thirumalachar (1950) on leaves of *Cassia fistula* from Bangalore in India. It has also been reported from Banaras by Payak (1949) and from Kallar-Burliar (Nilgiris) by Ramkrishnan T. S. and K. (1950) as *Phleospora cassiae* T. S. & K., which is probably synonym of *P. cassiae* Thirum. & Narasim. since the latter seems to have been validly published earlier (Ramkrishnan & Subramanian, 1952),

112. *Monochaetia jabalpurensis* Agarwal & Hasija on leaves of *Anogeissus latifolia* Wall, Berhaghat, November, 1959, Leg. Hasija.

Symptoms of the disease

The disease first appears as ash coloured pin head spots only on the upper surface of the leaf. Spots are usually circular with the central region ash coloured bounded by a dark brown margin. At maturity acervuli appear as small black dots in the central region. Spots are usually in aggregate near the midrib. Midrib and the chief veins are freely traversed.

The causal organism

Acervuli broad, disc shaped, brown, 99·2 – 195·3 μ wide, average 144·5 μ; conidia ellipsoid to fusoid, brown, 4 septate, end cells hyaline, central cells brown, with only one cilium at the apical end, 15·5 – 19·4 × 3·9 – 6·2 μ, average 18·3 × 5·8 μ, length of the coloured part, 9·3 – 13·9 μ. (Fig. 2).

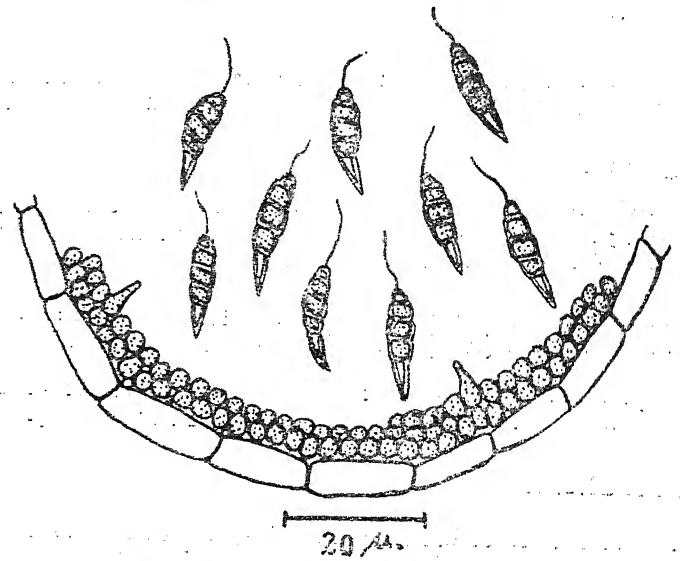

Fig. 2. *Monochaetia jabalpurensis*—Acervulus and spores.

So far no *Monochaetia* has been reported on *Anogeissus latifolia*. The specimen was examined by Mr. Sutton and he reported that it does not match with any recorded species of *Monochaetia*. It is, therefore, described here as a new species, *Monochaetia jabalpurensis*.

Monochaetia jabalpurensis Agarwal & Hasija sp. nov.

Acervuli brunnei, lati, discoidei, 99·2 – 195·3 μ lati; conidia ellipsoidea vel fusoidea, brunnea, 4-septata, cellulis terminalibus hyalinis, cellulis mediis brunneis, uno cilio ad apicem, 15·5 – 19·4 × 3·9 – 6·2 μ, medietate 18·3 × 5·8 μ, parte colorata 9·3 – 13·9 μ longa.

In foliis *Anogeissus latifoliae* Wall., ad Jabalpur, India, nov. 1959, leg Hasija.

The type specimen has been deposited in the Kew Herbarium No. 79168*a* and in the Dept. of Botany, Mahakoshal Mahavidyalaya, Jabalpur.

113. *Pestalotiopsis terminaliae* Agarwal & Hasija sp. nov. on leaves of *Terminalia bellerica* Roxb., Waterworks, October, 1959, Leg. Hasija.

Symptoms of the disease

The disease first appears as light brown pin head spots only on the upper surface of the leaf. Spots are circular to irregular, with the central region light

brown bounded by a dark brown margin. The green of the leaf around the spots becomes pale. At maturity acervuli appear in the central region as black dots. Spots rarely coalesce. The midrib and the chief veins are freely traversed.

The causal organism

Acervuli broad, light brown, superficial; conidia ellipsoid to fusoid, light brown, mostly 4 septate, end cells hyaline, central cells dark coloured, 2—3 cilia at the apical end, 10·9 – 18·6 × 3·9 – 6·2 μ, average 15·8 - 4·9 μ, length of the coloured part 7·8 - 15·5 μ, average 11·8 μ. (Fig. 3).

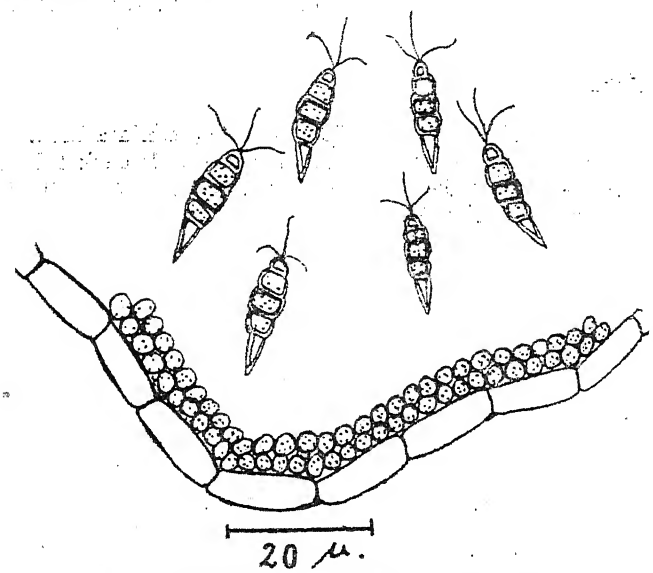

Fig. 3. *Pestalotiopsis terminaliae*—Acervulus and spores.

Pestalotiopsis disseminata (Thuem) Steyaert has been recorded on *Terminalia*. The material was examined by Mr. Sutton and he reported that this *Pestalotiopsis* is quite distinct from *P. disseminata*. It is, therefore, being described as a new species, *Pestalotiopsis terminaliae*.

Pestalotiopsis terminaliae Agarwal & Hasija sp. nov.

Acervuli lati, pallide brunnei, superficiales; conidia ellipsoidea vel fusoidea, pallide brunnea, 4-septata, cellulis terminalibus hyalinis, cellulis centralibus fuscis, ciliis 2-3 ad apicem, 10·9 - 18·6 × 3·9 - 6·2 μ, medietate 15·8 – 4·9 μ. Parte colorata 7·8 – 15·5 μ longa, medietate 11·8 μ.

In foliis *Terminaliae bellericae* Roxb. ad Jabalpur in India, mense octobri anni 1959, leg. Hasija.

The type specimen has been deposited in the Kew Herbarium No. 79750 and in the Dept. of Botany, M. M. V., Jabalpur.

114. *Pestalotiopsis woodfordiae* Agarwal & Hasija sp. nov. on leaves of *Woodfordia fructicosa* (Linn.) Curz, Waterworks, December, 1959, Leg. Hasija.

Symptoms of the disease

The disease first appears as dark brown spots from the upper surface of the leaf. The spots become irregular and light brown in the central region with dark brown margins. At maturity acervuli appear in the central region as black dot like structures. Often the green of a leaf around a spot turns pale. Spots often coalesce. Midrib forms a barrier. The whole tree gets badly infected.

The causal organism

Acervuli broad, superficial, 76·5 – 173·4 μ wide; conidia brown, ellipsoid to fusoid, 4 septate, deeply constricted at the septa, central cells dark coloured, straight or slightly curved, 15·5 — 25·5 × 6·4 – 10 μ, average 21·4 × 8·2 μ, length of the coloured part 10·2 – 17·5 μ. (Fig. 4).

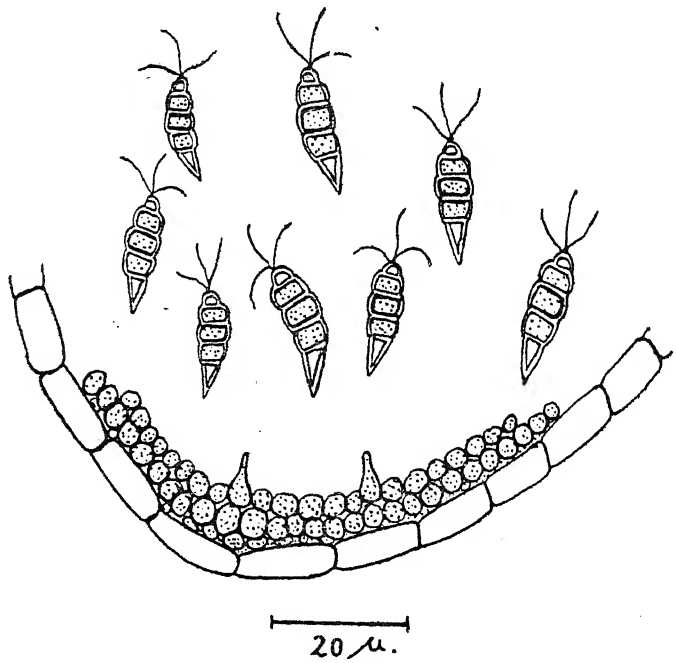

Fig. 4. *Pestalotiopsis woodfordiae*—Acervulus and spores.

So far there is no record of any *Pestalotiopsis* on *Woodfordia*. The specimen was examined by Mr. Sutton and he reported that nothing has been recorded which seems to fit this material. It is, therefore, being described as a new species, *Pestalotiopsis woodfordiae*.

Pestalotiopsis woodfordiae Agarwal & Hasija sp. nov.

Acervuli lati, superficiales, 76·5 – 173·4 μ lati; conidia brunnea, ellipsoidea vel fusoidea, 4-septata, alte constricta ad septa, cellulis terminalibus hyalinis, cellulis mediis fusce coloratis, rectis vel tenuiter curvatis, 15·5 – 25·5 × 6·4 – 10 μ, medietate 21·4 × 8·2 μ, parte colorata 10·2 – 17·5 μ longa.

In foliis *Woodfordiae fruticosae* (L.) Kurz, ad Jabalpur, India, dec. 1959, leg. Hasija.

The type specimen has been deposited in the Kew Herbarium No. 79167 and in the Dept. of Botany, M. M. V., Jabalpur.

115. *Pestalotiopsis japonica* (Syd.) Steyaert on leaves of *Ficus glomerata* Roxb., Waterworks, September, 1959, Leg. Hasija.

Symptoms of the disease

The disease first appears as small brown spots which become circular, less frequently angular. The central region becomes ashy and necrotic in which develop abundant pycnidia as black dots, only on the upper surface of thel eaf. Spots rarely coalesce and at times develop dumble shaped lesions. Later on shot holes are formed. Midrib and the chief veins are freely traversed.

The causal organism

Conidia ellipsoid to fusoid, brown, 4 septate, end cells hyaline, central cells coloured, 12·6 – 21·7 × 5·1 – 8·3 μ, average 19·8 – 6·2 μ.

Pestalotiopsis japonica is a new fungus record for India. *P. fici* has been reported on leaves of *Ficus religiosa* from Jabalpur (Madhya Pradesh) by Agarwal (1960). *P. elasticola* has been reported on living leaves of *Ficus elastica* from Badamatam (Darjeeling) by Ramkrishnan and Subramanian (1952).

The species has been identified by Mr. Sutton. The specimen has been deposited in the Kew Herbarium No. 77918.

116. *Periconia byssoides* Pers. ex Schw. on leaves of *Cassia tora* L., Waterworks, October, 1959, Leg. Hasija.

Symptoms of the disease

The disease first appears as brown pinhead spots which become circular to angular, dark brown in the central region bounded by a yellow margin, but at maturity the central region turns grey. Spots less often unite. Midrib and the chief veins are freely traversed.

The causal organism

Conidiophores dark brown, broadly thickened, arising singly, with broad base, long, stout, simple, at apex bearing loose head of conidia, 99·2 – 139·5 × 9·3 – 15·5 μ; conidia light brown, single celled, globose, 6·2 – 7·8 μ in diameter.

Periconia byssoides was first reported on dead stem of *Cassia* sp. from Madras state by Subramanian (1955) but *Cassia tora* is a new host record for the fungus.

117. *Alternaria citri* Pierce on leaves of *Citrus limonia* Risso, Wright Town, November, 1959, Leg. N. N. Lele.

Symptoms of the disease

The disease first appears as small yellowish spots on any part of the leaf. Spots are irregular in shape with central region yellow bounded by a light brown margin. The green of the leaf around the spots turns pale. Spots often coalesce. Later on the central region breaks away developing holes. Midrib is not crossed.

The causal organism

Conidiophores light to dark brown, in clusters, simple or branched, septate, with distinct geniculations, at times tips hyaline, 81·3 – 167·4 × 3·9 – 5·4 μ, average 106·6 × 4·7 μ; conidia dark brown, obclavate, usually with 3 transverse and one longitudinal septa, with or without beak, beak hyaline to subhyaline, nonseptate, epispore darker in colour, scars present, 18·6 – 68·2 × 7·8 – 18·5 μ, average 37·3 × 14·3 μ.

Alternaria citri Pierce was first reported from Bombay in India by Uppal (1934). It has also been reported on *Citrus* sp. from Ajmer by Joshi and Vashist (1959). It is a new record for the state.

118. *Helminthosporium erythrinae* Thirum. & Narasim. on leaves of *Erythrina indica* Rottl., Waterworks, September, 1959, Leg. Hasija.

Symptoms of the disease

The disease first appears as light brown pin head spots only on the upper surface of the leaf. Spots are circular to angular, with central region light brown bounded by a dark brown margin. At maturity clumps of conidiophores bearing conidia become evident as black dots in the central region. Spots often coalesce. The chief veins are freely traversed.

The causal organism

Conidiophores light to dark brown, septate, arising singly or in clusters, with distinct geniculations, 62 – 310 × 3·9 – 6·2 μ, average 140·1 × 5·4 μ; conidia cylindric, olivaceous, up to 13 septate, straight or more often curved, 27·9 – 111·6 × 3·1 – 6·2 μ, average 89 × 5 μ.

Helminthosporium erythrinae was first reported from Mysore in India by Thirumalachar and Narasimhan (1950) on leaves of *Erythrina suberosa*. *Erythrina indica* is a new host record for *H. erythrinae*.

The specimen has been deposited in Kew Herbarium No. 79163.

119. *Cercoseptoria balsaminae* Syd. on leaves of *Impatiens balsamina* L., Beoharbag, September, 1959, Leg. Agarwal.

Symptoms of the disease

The disease starts by yellowing of the leaf tissues. The lesions are irregular with central region light brown. At maturity fructification appears as small grey dots in the central region. Chief veins are freely traversed. Almost the whole leaf gets involved.

The causal organism

Conidiophores dark brown, obsolete; conidia hyaline to light coloured, 2 - 9 septate, filiform, tapering towards the upper end, straight or curved, 20·3 - 83·7 × 2·3 - 3·1 μ, average 36 - 2·9 μ.

It is a new record for the state. The material is deposited in Kew Herbarium No. 79004 and in the Botany Dept., M. M. V., Jabalpur.

SUMMARY

The present paper describes 12 deuteromycetes causing leaf spots on different hosts at Jabalpur. *Pyrenochaeta tandonii* Agarwal & Hasija on *Tephrosia purpurea*, *Monochaetia jabalpurensis* Agarwal & Hasija on *Anogeissus latifolia*, *Pestaloliopsis terminaliae* Agarwal & Hasija on *Terminalia bellerica* and *Pestalotiopsis woodfordiae* Agarwal & Hasija on *Woodfordia fructicosa*, are the four new species described. *Pestalotiopsis japonica* (Syd.) Steyaert on *Ficus glomerata* is a new fungus record for the country. *Cassia tora* for *Periconia byssoides* Pers. ex Schw. and *Erythrina indica* for *Helminthosporium erythrinae* Thirum. & Naras. are new host records. *Phyllosticta ipomoeae* Ell. & Kellerm on *Ipomoea* sp., *P. sesbaniae* Syd. on *Sesbania grandiflora*, *Phleospora cassiae* Thirum. & Naras. on *Cassia fistula*, *Alternaria citri* Pierce on *Citrus limonia* and *Cercoseptoria balsaminae* Syd. on *Impatiens balsamina* are new records for the state.

ACKNOWLEDGEMENTS

The authors express their grateful thanks to Dr. J. C. F. Hopkins, Director, Dr. M. B. Ellis, Mr. F. C. Deighton and Mr. Sutton, Assistant Mycologists, Commonwealth Mycological Institute, Kew, England for the identification of the species and to Rev. Fr. Prof. H. Santapau, Director of Biology section, St. Xavier's College, Bombay for his kindness in rendering in to Latin the diagnoses of the new species. Our thanks are also due to the Principal and the Head of the Botany Department, Mahakoshal Mahavidyalaya, Jabalpur for Laboratory facilities and to the University of Jabalpur for kindly sanctioning a Research Grant to the senior author.

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ON THE PALATAL ORGANS OF *LABEO DERO* (Hamilton).

By

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Majumdar (1952) while describing the palatal organs of *Cirrhina mrigala* (Hamilton) mentioned the presence of similar type of palatal organs in the small cyprinoid fish *Labeo dero* (Ham.). The present paper gives the anatomy and histology of these organs in this fish.

MATERIAL AND METHODS

Living fishes were collected from the river Jumna. Specimens were killed and fixed in formalin by dropping the living fish into the formalin solution. Palatal tissues were fixed in Bouin's fluid and sections were cut at 6 and 8 μ and stained with Delafield's haematoxylin and counter-stained with Eosin.

Labeo dero is a carp that is very common in the river Jumna and it grows to about 8 inches in length. Smaller fish are more common in the river and are specially abundant during the months of January and February.

MOUTH AND THE PALATE

The mouth is placed antero-ventrally and it is crescentic in shape (Fig. 1, mo.). It is bounded anteriorly by the upper jaw and a fleshy anterior (upper) lip, (u. l.). Posteriorly it is bounded by the lower jaw and a thin lower lip, (l. l.). The lips are non-protractile.

The mouth leads into a spacious buccal cavity which bears a series of comb plates, folds and papillae in its anterior half and many long papillae in the posterior half. For the sake of description the palate may be divided into four regions :—

(1) The comb-plate region or region of the depressed area having the comb plates (Fig. 2. dep.).

(2) The lateral ridge region or region of the lateral ridges or folds (fl.).

(3) The tubercular region or region of the tubercular protuberances (tu.)

(4) The papillated region or region of the posterior half of the palate with papillae on it (p. p.).

(1) Region of the depressed area :—In the anterior region of the palate there is an oval depressed area from which arise a number of thin comb shaped plates.

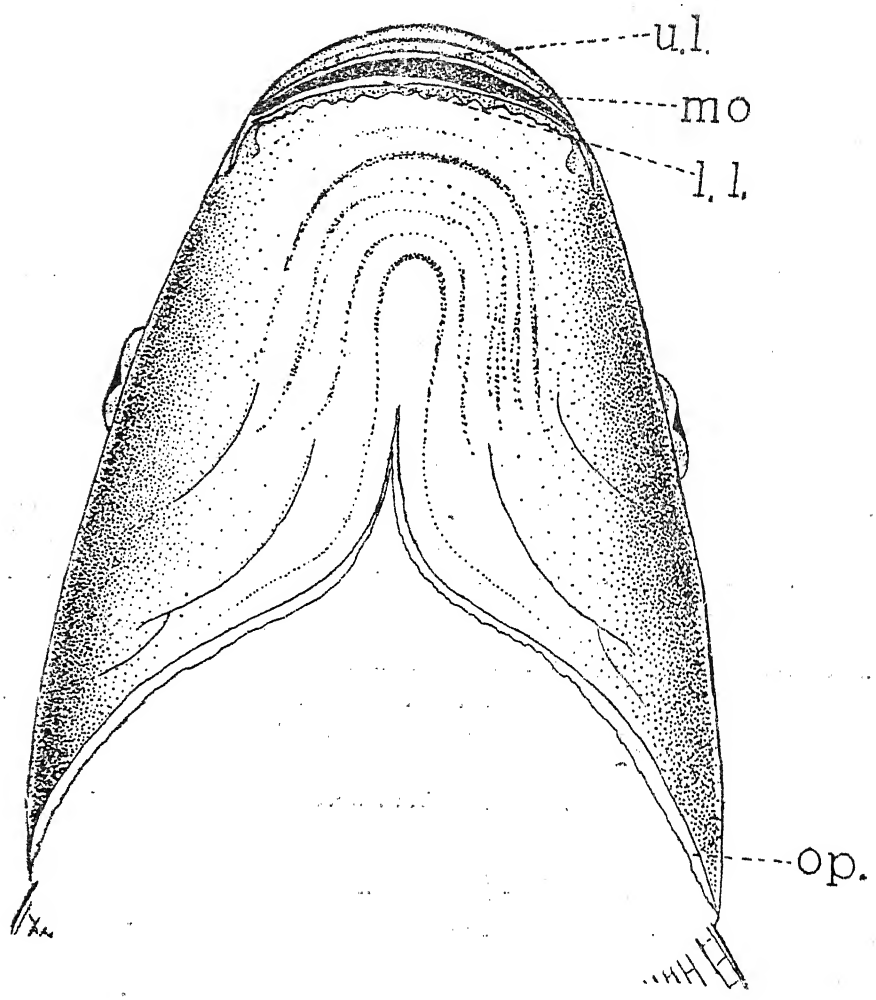

Fig. I. Head of *Labeo dero* showing the ventral position of the mouth. ×31/2, l. l., lower lip; mo., mouth; op., operculum; u. l., upper lip.

These plates (Fig. 2. dep.) are extensions of the buccal lining and are like those of *Cirrhina mrigala*; only they are not arranged in two complete rows and are placed in an irregular manner. There are 8 to 10 large plates and about the same number of small reduced plates. The larger plates are, however, arranged in two rows. The free margin of each plate has many papillated projections which give the plate the appearance of a small comb. Each plate freely hangs down from the roof of the mouth into the buccal cavity.

(2) *Region of the lateral ridges or folds* :—On the antero-lateral sides of the depressed area the buccal lining is raised into two longitudinally placed ridges or folds (Fig. 2. fl.). The ridges are provided with many small subsidiary folds and are devoid of papilla. Each fold in a young fish appears as a plain extension of the buccal lining, but as the fish grows this becomes pleated and there develop several subsidiary folds from its sides and it becomes a complicated fold which assumes a wavy appearance. The area immediately on the two sides of these ridges is raised into many minute tubercular outgrowths which can be seen only with the aid of a hand lens.

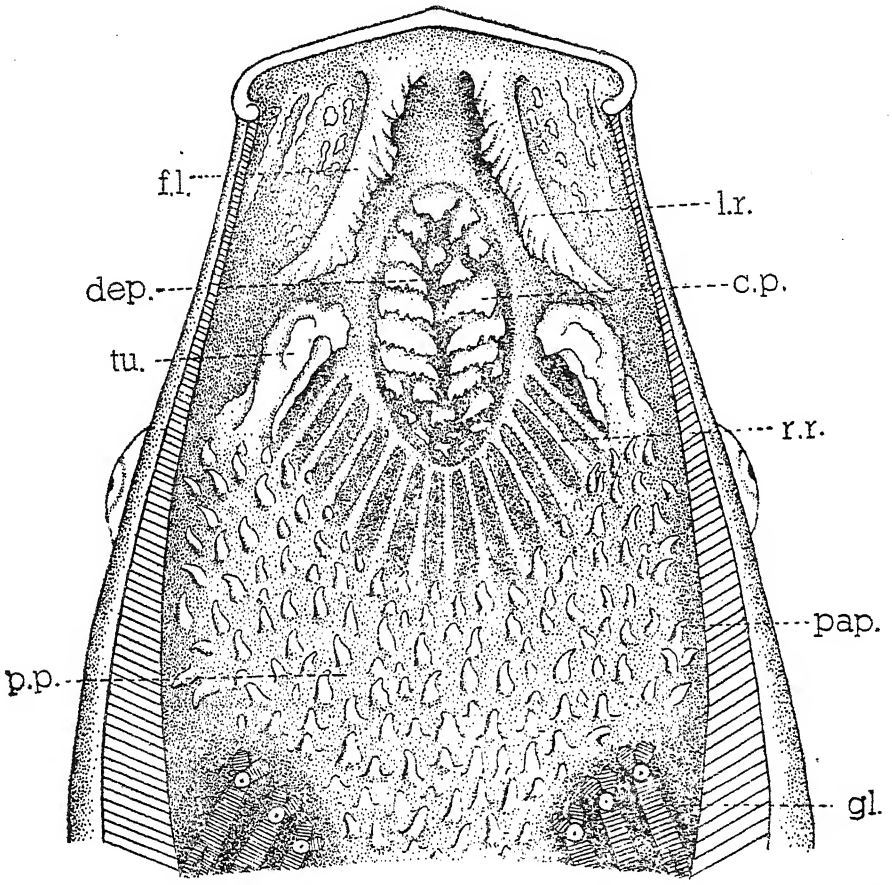

Fig. II. Palate of *Labeo dero* × 3 ; c. p., comb plate; dep., region of the depression; fl., region of the folds; gl.. gill; l. r., longitudinal folds; pap., papilla in the posterior region of the palate; p. p., region of the posterior part of the palate; t. u., tubercle; r. r., radiating ridge.

(3) *Region of the tubercular protuberances* :—The palatal lining on the two sides of the depressed area is modified into two protuberances (Fig. 2. tu.). These are simple tubercular outgrowths in a young fish and as the fish grows there develop finger-like processes on these which make it complicated.

In the region immediately behind the depressed area the buccal lining is produced into a series of regular plates which are in the form of small radiating ridges and furrows. (Fig. 2 rr.)

(4) *Region of the Posterior half of the plate* :—Rest of the palate behind the radiating ridges is strewn with many elongated conical papillae (Fig. 2 pap.). These papillae are simple and do not bear any subsidiary papillae like those of *Cirrhina mrigala*. Most of the papillae are directed anteriorly and each papilla measures from 0·5 to 1 mm. in length in a 10·3 cm. long fish.

Histology of the different regions :

(*1*) *The comb plates* :—The epithelial lining of the comb plates is rich in saccular mucous cells and has only a thin layer of stratified cells (Fig. 3 s. c.).

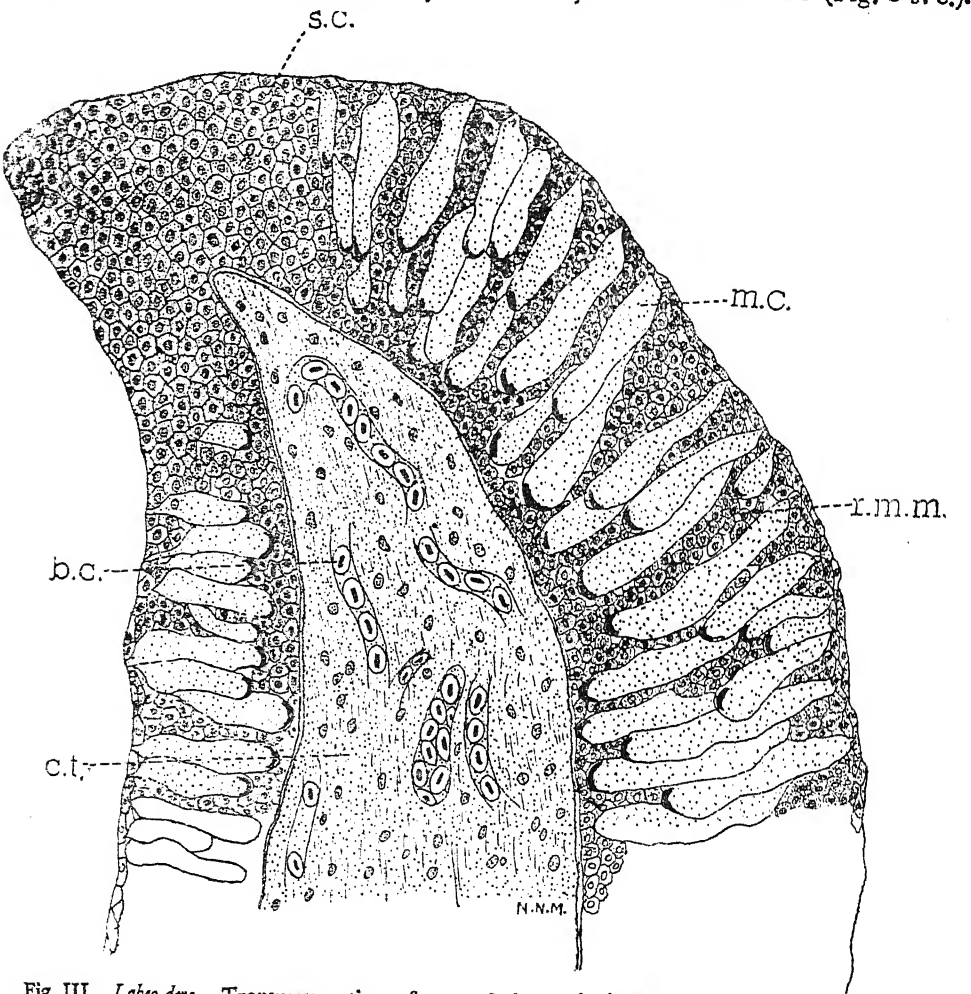

Fig. III. *Labeo dero.* Transverse section of one of the comb plate×268 ; b. c., blood cells. c. t., connective tissue; m. c. mucous cell; r. m. m., rete mucusum Malpighii; sc., cornified cell.

Along the free margin of a plate the cells of the epithelium are polygonal, they are compact and are somewhat cornified. This cornification of the marginal epithelial cells extends to a little distance along the inner surface of each plate. The taste-buds are few in number in this region.

The basement membrane below the epithelial layer is very thin. The underlying submucosa forms the base and core of these plates. This layer is composed of connective tissue which is rich in blood capillaries (b. c.) These capillaries run up to the basement membrane. Each plate at its base has a group of vasicular cells. There are very few muscle fibres running into the submucosa of the comb plates.

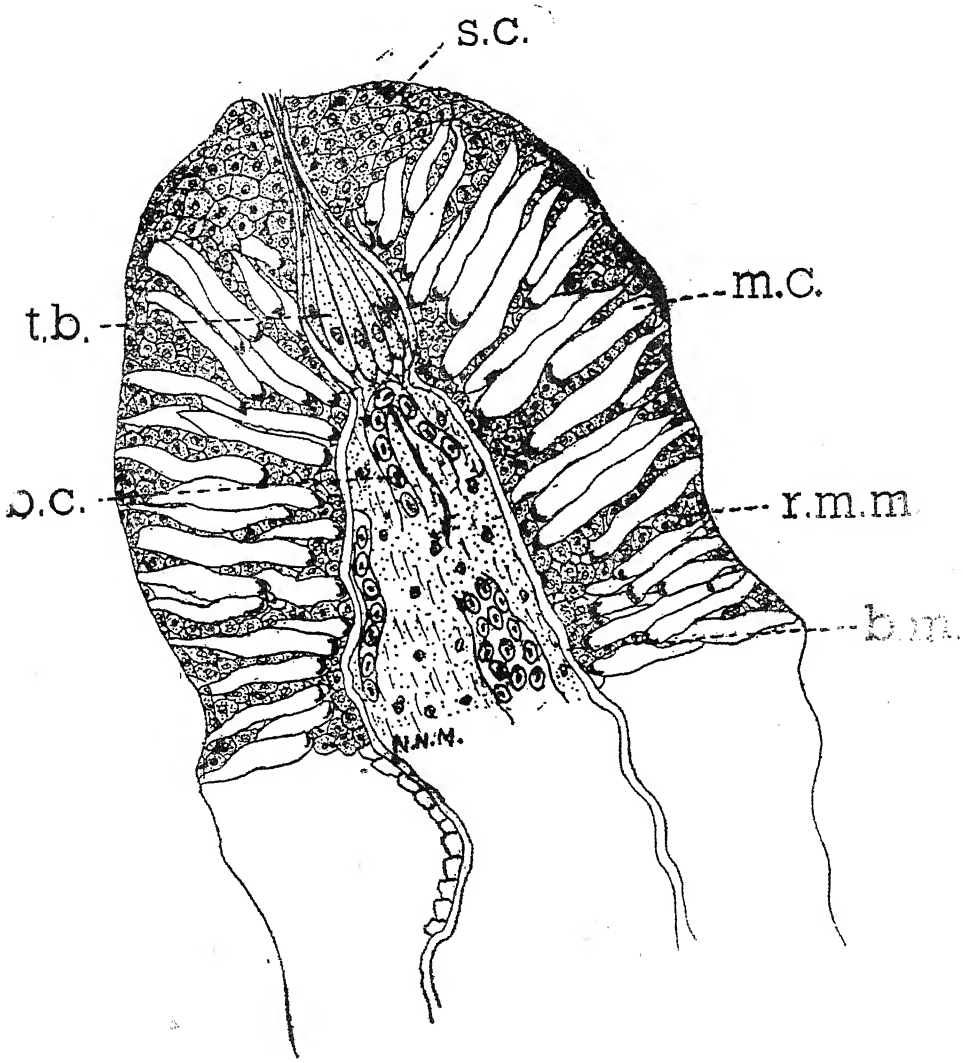

Fig. IV. *Labeo dero.* Longitudinal section of one of the finger like projections on the tubercles × 280; b. m., basement membrane; t. b., taste bud; other letterings as in Fig. I.

(2) *Lateral ridges* :—The epithelial layer of the lateral ridges is similar to that of the comb plates, only there is no cornification of the cells in this region. The taste buds and mucous cells are as numerous as in the epithelium of the comb plates. The basement membrane, though thin, is quite distinct. The submucosal core is

rich in blood vessels, and in the submucosa, the vesicular cells are absent. There are many striated muscle fibres lying scattered in the submucosal core of these ridges.

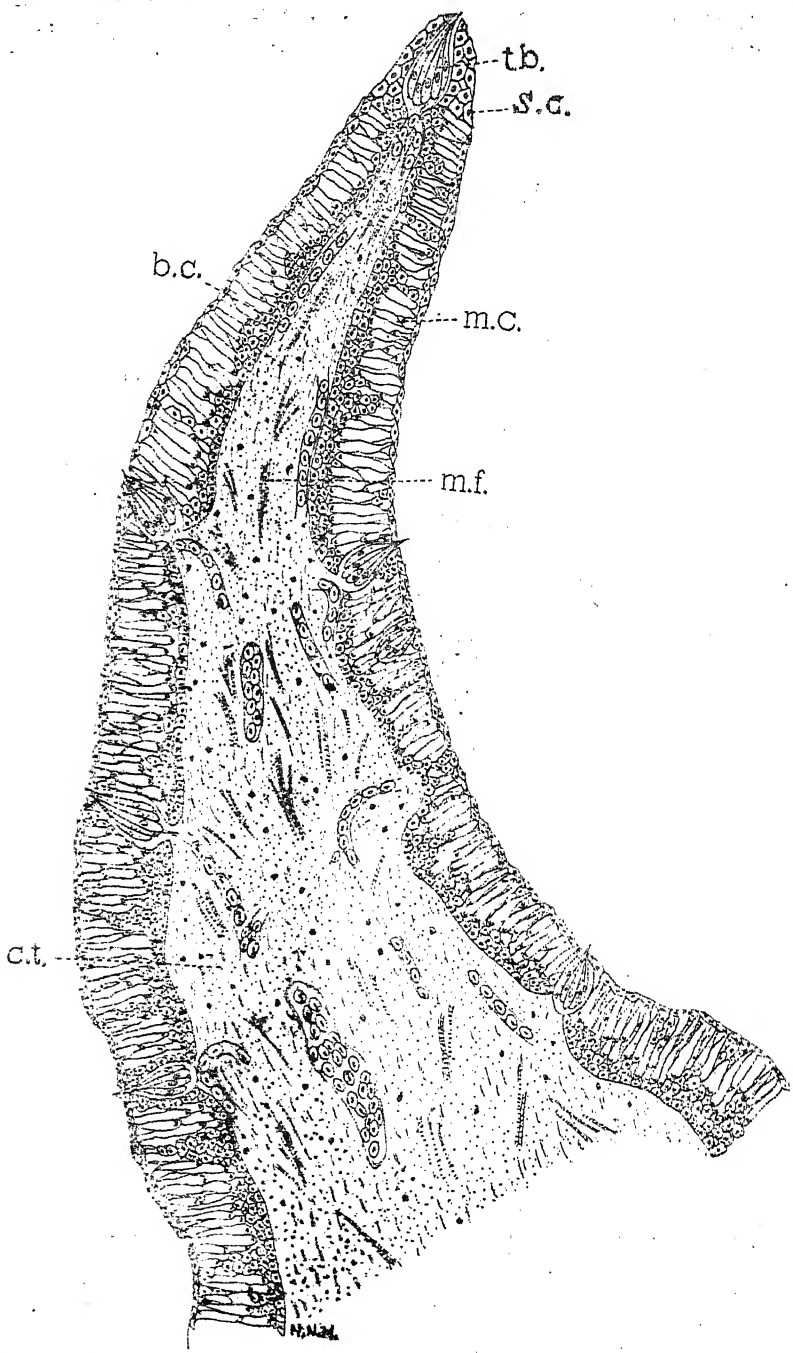

Fig. V. *Labeo dero* Longitudinal section of one of the papillae on the posterior region of the palate. × 130 ; m. f., muscle fibre ; t. b., taste bud ; other letterings as in Fig. III.

(3) *Tubercular protuberances* :—In this region the buccal lining bulges into a tubercle on each side, a structure somewhat similar to the "palatine cushion" in *Gobio* described by Al-Hussaini (1949). In grown up specimens there develop some minute fingerlike processes over these tubercles (Fig. 4). The epithelial covering of these processes is similar to that of the lateral ridges but there are numerous taste-buds in it. Each taste-bud at its tip is surrounded by a patch of cornified cells. The sub-epithelial tissue is very similar to that of the lateral ridges.

(4) *Papillae on the posterior region of the palate* :—The epithelial layer on the papillae has innumerable mucous cells (Fig. 5 m. c.) and the number of taste-buds (t. b.) in this region is very large in comparison with that of the other regions of the palate. The stratified nature of the superficial layer is very apparent and the tips of most of the papillae have small patches of polygonal cornified cells. The basement membrane is very thin and the underlying connective tissue layer has voluntary muscle and blood vessels but vesicular cells are not aggregated into groups in this layer.

To ascertain the utility of the papillae and of the comb plates in the case of *Labeo dero*, some observations on the respiration were made. Several specimens of different sizes were kept on moist sand and duration of theirsurvival outside water was recorded.

Name of the fish	Number of specimens	Size in Stnd. length (in inches.)	Approximate average time of life outside water.
Labeo dero	10	7·5 to 8	24 minutes.
	6	5·1 to 6	18 minutes.
	8	2·2 to 4·6	16 minutes.

CONCLUSIONS

These observations show that carps with modified palatal surface like *Labeo dero* can survive for a considerably longer period outside water than those without such structures on their palate.

The carp referred to in this paper is a bottom living form, a region always deficient in dissolved oxygen, so this fish requires a greater area to take up oxygen. This is provided by the plates and papillae mentioned above in addition to the normal gills.

Examination of gills of *Labeo dero* does not reveal any modification in them. The skin being covered with scales cannot presumably serve much of a respiratory function. Longer duration of life of this fish even outside water is made possible by the oxygen it absorbs through these structures on the palate and partly through the gills.

SUMMARY

The present paper describes the palatal organs of *Labeo dero*. These organs may be conveniently placed in the following regions :

(1) Region of the depressed area having the comb plates.

(2) Region of the lateral ridges of folds.

(3) Region of the tubercular protuberances.

(4) Region of the posterior half of the palate with papillae on it.

The number of comb plates is from 8 to 10 large ones and the same number of smaller plates. The histological structure of the palatal organs consists of large number of mucous cells, cornified epithelial cells and a few taste-buds. The mucosa is supported by a vascular submucosa.

The results of the experiments performed and also the vascularity of the plates and papillae point to their respiratory function.

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